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Assessment of compliance in grass-fed cattle and evaluation of increasing accuracy of BeefSpecs inputs

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Abstract

This project was conducted to: (1) gain a better understanding of compliance rates in grass-fed cattle, and (2) conduct a sensitivity of the BeefSpecs fat calculator inputs to determine their impact on predictive accuracy. Two commercial datasets (A and B) were obtained to determine compliance rates to carcass specifications in grass-fed steers and heifers and the results suggest that 10-20% of carcasses are not compliant with hot standard carcass weight (HSCW) and/or fatness specifications. Non-compliance rates for steers in dataset A (n = 18,860) were found to be 17.4% and 13.0% for HSCW and rib fat, respectively. These non-compliance rates resulted in a total gross income loss of $634,767 for all steers in dataset A. When averaged across all steers, this income loss equates to $33.66 per carcass.

The non-compliance rates for heifers (n = 13,118) in dataset A were 15.6% and 19.1% for HSCW and rib fat, respectively. These non-compliance rates resulted in a total gross income loss of $325,619. When averaged across all heifers, the income loss equates to $24.82 per carcass. Relatively high non-compliance rates in dataset B suggested that the indicative grid supplied by the abattoir for this dataset was not relevant and therefore exaggerated non-compliance rates and income losses.

The Taguchi Quality Loss (TQL) function has been used in the engineering sector to determine the economic loss incurred by consumers when products do not meet specific targets, and has been used to assess economic losses due to non-compliance in feedlot cattle. The TQL was applied in this study to predict the economic loss of non-compliance on the processing sector. Predictions of losses by TQL were relatively small when the range of carcass traits was close to the ‘sweet spot’ of carcass grids. Beyond this range, however, TQL predictions quickly, and increasingly, exaggerated the costs of non-compliance. The TQL function is therefore not appropriate for analysing the economic losses incurred by abattoirs from carcass non-compliance to specifications.

The Beefspecs calculator uses estimates of current liveweight, frame score and P8 fat (mm), to predict final liveweight and fat cover. Errors around initial frame score and initial P8 fat significantly affect the accuracy of final P8 fat predictions. However, final P8 fat predictions were much less sensitive to errors in estimating initial liveweight. Errors in predicted final P8 fat per unit frame score error were up to 2.3 mm in heifers and up to 1.7 mm in steers. Errors in predicted final P8 fat per mm error in initial P8 fat were up to 1.5 mm in both heifers and steers. These prediction errors have important consequences for the application of the BeefSpecs fat calculator in the beef industry.

Executive summary

This project was conducted to: (1) gain a greater understanding of the economic impacts of non-compliance in grass-fed beef carcasses, and (2) gain an understanding of the sensitivity of the BeefSpecs fat calculator to errors in key input traits. The first component involved two large commercial datasets containing approximately 32,000 (dataset A) and 33,500 (dataset B) useable grass-fed carcass records, with each dataset containing steers and heifers. The second component assessed the sensitivity of BeefSpecs predictions to error in the inputs of frame score, initial P8 fat and initial liveweight.

Compliance rates to market specifications of grass-fed beef cattle
Non-compliances rates in each dataset were assessed using two carcass specification grids, supplied by the respective processors, with each grid based on hot standard carcass weight (HSCW) and P8 fat. As the two datasets contained rib fat measurements, rather than P8, the carcass grids were converted to indicative grids based on the former fat measure.

The non-compliance rates of steers in dataset A (n = 18,860) were found to be 17.4% and 13.0% for HSCW and rib fat, respectively. These non-compliance rates represent a total gross income loss of $634,767 for all steers in dataset A. When averaged across all steers (n = 18,860) this income loss equated to $33.66 per carcass.

The non-compliance rates for heifers (n = 13,118) in dataset A were 15.6% and 19.1% for HSCW and rib fat, respectively. The total gross income loss was $325,619 for all heifers in dataset A. When averaged across all heifers (n = 13,118) contained in dataset A the income loss equates to $24.82 per carcass.

The differences in HSCW losses between steers and heifers in dataset A were due to a higher proportion of the non-compliant heifer carcasses being under-weight compared to a higher proportion of steer carcasses being over-weight. The differences in rib fat losses were due to more heifers being over-fat thus attracting higher price discounts compared to steer carcasses.

The non-compliance rates in dataset B for steers (n = 12,694) were found to be 44.8% and 18.5%, for HSCW and rib fat, respectively. The total gross income loss was $747,885 for all steers in dataset B. When averaged across all steers (n = 12,694) contained in dataset B the income loss equates to $58.92 per carcass. The non-compliance rates and income losses for rib fat are comparable to those from steers in dataset A, however the HSCW non-compliance rates were higher, and thus the total income loss and income loss per steer carcass in the dataset were also higher.

The corresponding non-compliance rates for heifers (n = 20,848) in dataset B were 88.2% and 14.3% for HSCW and rib fat, respectively. The total gross income loss was $1,718,447 for all heifers in dataset B. When averaged across all heifers (n = 20,848) the income loss equates to $82.43 per carcass. Compared to the heifers in dataset A the non-compliance rate for HSCW and associated income losses were substantially higher. The rib fat compliance rate was slightly lower that seen in dataset A which is reflected in the lower income losses.

The non-compliance rates for HSCW in dataset B suggest that the indicative grid supplied by the commercial abattoir was not appropriate for this dataset and are thus not a good indication of true non-compliance rates in the grass-fed component of the

Australian beef industry. The results for dataset A suggest that 10-20% of grass-fed beef carcasses are not compliant with carcass HSCW and fatness specifications. These values are broadly consistent with previous studies of non-compliance in feedlot cattle.

Predicting the economic impact of non-compliance on the processor
The Taguchi Quality Loss (TQL) function was trialled as a predictor of losses incurred by the processing sector due to non-compliance. The economic costs of carcasses close to the target HSCW (280 kg) were found to be relatively small in dataset A. A 270 kg carcass was predicted to lose $2.78 while a 290kg carcass was predicted to lose $4.58. In contrast, carcasses with large deviations from the target value had extremely large losses. A 130 kg carcass was predicted to lose $625.00 and a 510 kg carcass was predicted to lose $2,424.58. In a ground-truthing exercise a 510 kg carcass was calculated to be worth $3,000.07 when sold at full value and the carcass grid indicated the abattoir would only have paid $1,020.00 for that carcass. The economic costs of carcasses that have small deviations from the target rib fat value of 7.5 mm were also found to be relatively small. A 280 kg carcass with 6 mm of rib fat was predicted to lose $20.45 while a 280 kg carcass with 9 mm of rib fat was predicted to lose $9.30. Reflecting the results found for HSCW, carcasses with large deviations from the target rib fat value had extremely large losses. A 280 kg carcass with 0 mm of rib fat was predicted to lose $511.36 and a 280 kg carcass with 30 mm of rib fat was predicted to lose $2,091.94. The ground-truthing exercise calculated a 280 kg carcass with 30 mm of rib fat was worth $1,773.80 while the carcass grid indicated the abattoir would only have paid $644.00 for that carcass.

A similar pattern was found for dataset B with the predicted losses for carcasses most divergent from target values being more extreme than those for dataset A. The differences in absolute financial losses compared to dataset A were due to the carcass grid for dataset B having a much more stringent ideal HSCW range. These results show that the TQL function is not appropriate for analysing the economic losses incurred by abattoirs from non-compliant carcasses.

Beefspecs sensitivity
Inaccuracy in estimates for frame score and initial P8 fat significantly decreased the accuracy of BeefSpecs predictions of final P8 fat, while errors in estimating initial live weight had much less of an effect. Errors in final P8 fat per unit of frame score error were up to 2.3 mm in heifers and up to 1.7 mm in steers. Errors of 1.53 mm in the prediction of final P8 fat could occur per mm error in estimating initial P8 fat.

Conclusions
If the non-compliance income losses estimated from dataset A are extrapolated to all grass-finished cattle, the Australian beef industry is losing, potentially, millions of dollars in annual on-farm returns. The actual cost to industry depends on how readily, and at what cost, non-compliance rates can be reduced. Future work should assess the relative ease, cost-effectiveness and practical value of different options for reducing non-compliance rates.

The BeefSpecs calculator, a tool for helping reduce non-compliance rates, is clearly sensitive to the accuracy of initial frame score and P8 fat estimates. Appropriate training and/or alternative measurement technologies, will be required to ensure that BeefSpecs produces reliable outputs to assist decision-making of producers.

Acknowledgements

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1. Background

Huge benefits can be gained from using current and future technologies to connect rural Australia and provide real time interactive livestock data to better describe cattle at the point of sale. It has been estimated that a 50% reduction in non-compliance rates to market specifications in the grass-fed component of the Australian beef industry would result in a net present value (NPV) of $43.5 million over 15 years (Beef CRC phenotypic prediction report (2011); note this analysis excluded R&D costs and the values are 8 and 15 years post CRC and adjusted for risk for 1M and 1/2M grassfed cattle respectively for BeefSpecs and BeefSpecs "On-Farm Drafting Tool");]. An interactive beef trading system that linked prediction systems such as BeefSpecs to 3D visual image analysis systems to estimate live animal traits such as P8 fat would assist producers, feedlot managers, and processors improve efficiency and profitability.

The benefits of a beef trading system include:

- ✓ Instantaneous feedback on animal suitability for different target market(s);
- ✓ Improving management and genetics of livestock to meet market targets via linkages to central databases; and
- ✓ Assisting producers address ways to improve profitability and processors source stock to better meet market specifications.

The first steps in developing an interactive beef trading system are to quantify non-compliance of grass-fed cattle and to evaluate the effects measurement error in key BeefSpecs inputs have on prediction accuracy. To undertake the analysis of compliance rates in grass-fed cattle, two commercial in-confidence datasets, containing approximately 32,000 (dataset A) and 46,000 (dataset B) carcasses respectively, have been used. Analysis of both datasets containing steers and heifers was conducted based on current commercial pricing schedules supplied by commercial abattoirs.

2. Objectives

1. Economic assessment of improving compliance in southern grass fed cattle.
2. Evaluation of methods to improve the measurement accuracy for key inputs into BeefSpecs.

3. Compliance in southern grass-fed cattle

3.1 Introduction

Anecdotal evidence has been the primary justification for non-compliance to market specifications being raised as an important issue affecting profitability in the Australian beef industry. Slack-Smith et al. (2009) examined carcass compliance rates in two feedlot datasets containing 40,000 individual animals obtained from the processing sector. In the dataset containing 20,000 short-fed animals, it was demonstrated that 28% missed carcass weight specifications and 16% missed P8 fat specifications.

These findings are specific to the feedlotting sector and shed no light on non-compliance rates in grass-fed beef cattle. Consequently, the current study was initiated to quantify non-compliance rates in grass-fed beef cattle. Compliance rates and price penalties received by producers are reported for steers and heifers in two datasets based on current pricing schedules. Economic costs to processors of non-compliant carcasses were estimated using the TQL function, which was also used in the Slack-Smith et al. (2009) study.

3.2 Methodology

Determining compliance rates and price penalties.
Compliance rates to carcass specifications and the price penalties received by non-compliant carcasses were determined using a 3 step process.

1) The commercial pricing schedules supplied by commercial abattoirs were used to develop the carcass grids for each dataset. The datasets used in this study contained hot standard carcass weight (HSCW) (kg) and cold carcass rib fat (mm). The commercial carcass grids obtained from relevant abattoirs contain HSCW and P8 fat (mm) as market specifications. This discrepancy between the datasets and commercial carcass grids for rib and P8 fat was overcome by using the relationship between P8 fat and rib fat contained in the fat scoring system presented in Table 1 (McKiernan and Sundstrom 2006) to convert the commercial grid to a indicative grid that uses rib fat rather than P8 fat as a specification.

Table 1. The relationship between P8 and rib fat contained in the fat scoring system presented by McKiernan and Sundstrom (2006) which was used to convert commercial carcass grids containing P8 fat to indicative grids that use rib fat as a specification.

Fat Score	**1**	**2**	**3**	**4**	**5**	**6**
P8 fat (mm)	0-2	3-6	7-12	13-22	23-32	33+
Rib Fat (mm)	0-1	2-3	4-7	8-12	13-18	19+

2) The carcass data contained in each dataset were compared to the relevant carcass grid to determine the proportion of carcasses that received no pricing discounts. This comparison was initially conducted for HSCW and rib fat independently. Subsequently, compliance rates were determined using HSCW and rib fat simultaneously.

3) The pricing discounts for each carcass were multiplied by their respective HSCW to determine the total financial loss incurred by the producer for that particular carcass. These losses were summed to determine the total financial loss relevant to each dataset. For completeness the average loss per animal contained in each dataset and per animal that missed carcass specifications are presented.

Estimating economic costs for the processor

The economic costs of carcasses not complying with specifications were estimated using the TQL function. The TQL function is a statistical method applied extensively in the manufacturing sector to determine the costs incurred by society when products vary from an optimal production target. The TQL function is (Equation 1):

$$L(y) = k(y-m)^2 \qquad \text{Equation 1.}$$

where L(y) is the economic cost of deviating from the target, k is an economic constant called the quality loss coefficient, m is the target value (Patil et al. 2002) and y is the trait of interest. The quality loss coefficient is the deviation a product is from the target when an average consumer takes action to correct the deviation defined as (Equation 2):

$$k = \frac{A_o}{\Delta_o^2} \qquad \text{Equation 2.}$$

where Δ_o is the difference between the target, m, and the point of intolerance, t (Figure 1). The point of intolerance is considered the point beyond which action is taken to correct a deviation from the target. A_o is the economic costs incurred when taking corrective action at the point of intolerance (Sharma et al. 2007).

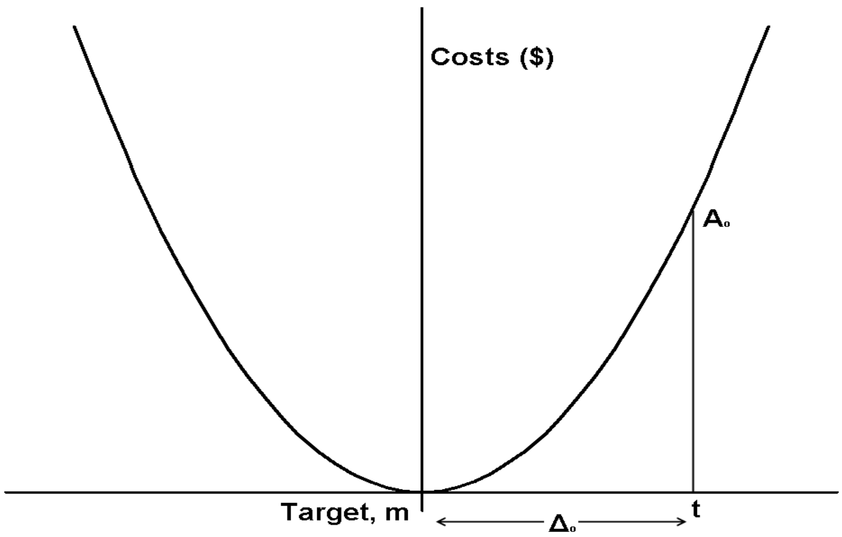

Figure 1. Taguchi Quality Loss Function for estimating economic costs when products do not meet target values.

The TQL function was applied to carcass compliance rates by considering the producer as being analogous to a manufacturer and the processor as analogous to a consumer. Viewing the producer/processor relationship in this manner allowed the carcass grids to be used to determine parameters in Equations 1 and 2. As demonstrated below carcass grids don't have an optimal target rather they allow some variation to occur before price penalties are applied. The range where no discounts are applied was used to give an indication of the consumers (processor) intolerance points. The point of intolerance, t, was assumed to be the edge of the trait range where price discounts were not applied. Consequently, the target value, m, was assumed to be the median value of the trait range where price discounts were not applied and Δ_o, the difference between the target value and the point of intolerance.

The monetary loss values, A_o, were determined as the economic loss to the consumer (processor) due to them being required to take action to accommodate the deviations in carcass traits from the specifications in order to on-sell the product. When considering deviations from ideal HSCW specifications these losses were assumed to be due to reductions in average price received for primals due to the primals producing over- or under-sized cuts. The monetary losses associated with carcasses that had HSCW lighter than ideal were considered to differ to the monetary losses associated with carcasses that had HSCW heavier than ideal. These differences are a reflection of the differences in carcass weight. For example, a 220 kg carcass and a 340 kg carcass are both 60 kg different to a 280 kg carcass but if a $1/kg HSCW is applied to both carcasses the 220 kg carcass will lose $220.00 where as the 340 kg carcass will lose $340.00. When considering deviations in rib fat from ideal, under-fat carcasses were considered to receive reductions in average primal price similar to HSCW deviations due to the primals needing to be siphoned into alternative markets (e.g. lean meat markets) in order to sell the product. In contrast, when considering over-fat carcasses the losses were assumed to occur in saleable meat yield percentage due to extra fat trimming being required to achieve primals with desired levels of external fatness. It should be noted that this method for determining A_o either side of the target value is in contrast to traditional applications of the TQL function. Examples of how these values were calculated when HSCW and rib fat failed to comply with specifications are presented below.

- *HSCW monetary losses*

A 280kg carcass with ideal fatness was considered to have a 70% retail meat yield producing 196kg of saleable meat. This saleable meat is partitioned between saleable cuts and grinding beef in the ration 70:30 resulting in 137.2kg of saleable cuts and 58.8kg of grinding beef. If the processor can sell the grinding beef for $4.50/kg and the cuts for $11/kg (M. McDonagh pers. comm., 2014) then the 196kg of saleable meat is worth $1,773.80. However, if the processor can only sell the saleable cuts for $10/kg (a 9% reduction in price) due to issues with portion size then the 196kg of saleable meat is worth $1,636.60. The reduction in price results in a $137.20 economic loss (or A_o).

- *Rib fat monetary losses*

An under-fat 280kg carcass is assumed to produce the same 196kg of saleable meat. However, due to the lack of fat cover it is assumed the processor would only be able to sell the saleable cuts for $9/kg meaning the 196kg of saleable meat is worth $1,499.40 rather than $1,773.80. This equates to an economic loss (A_o) of $274.40. In contrast, an over-fat carcass would still produce saleable cuts worth $11/kg but the retail meat yield of such a carcass could be reduced to 65% rather than 70% when rib was 16 mm (P8 fat = 28mm). This yield reduction would reduce the quantity of saleable meat to 182kg and its value to $1,647.10. The subsequent economic loss (A_o) is $126.70.

The assumed values for calculating the economic losses of each dataset will be given below when analysis using the TQL function is presented. The economic losses estimated by the TQL function for both datasets A and B are assumed to be the same for both steers and heifers due to meat being indistinguishable between steers and heifers when in the form of saleable primals.

3.3 Results and discussion

3.3.1 Compliance Rates and Price Penalties

3.3.1.1 Dataset A

- Steer HSCW Results

Figure 2 shows the discount associated with HSCW (MSA graded market) between 130 and 519 kg in an indicative grid relevant for steers from dataset A supplied by a commercial abattoir. HSCW in the range 220 to 339 kg receive no discount in price with discounts increasing in size as HSCW moves further in each direction away from this ideal range. It is quite evident that carcasses below 160 kg receive large discounts (>$2.00/kg HSCW). It is also evident discounts received by carcasses in the ranges 180-219kg and 340-359kg are relatively small ($0.10-$0.20/kg HSCW).

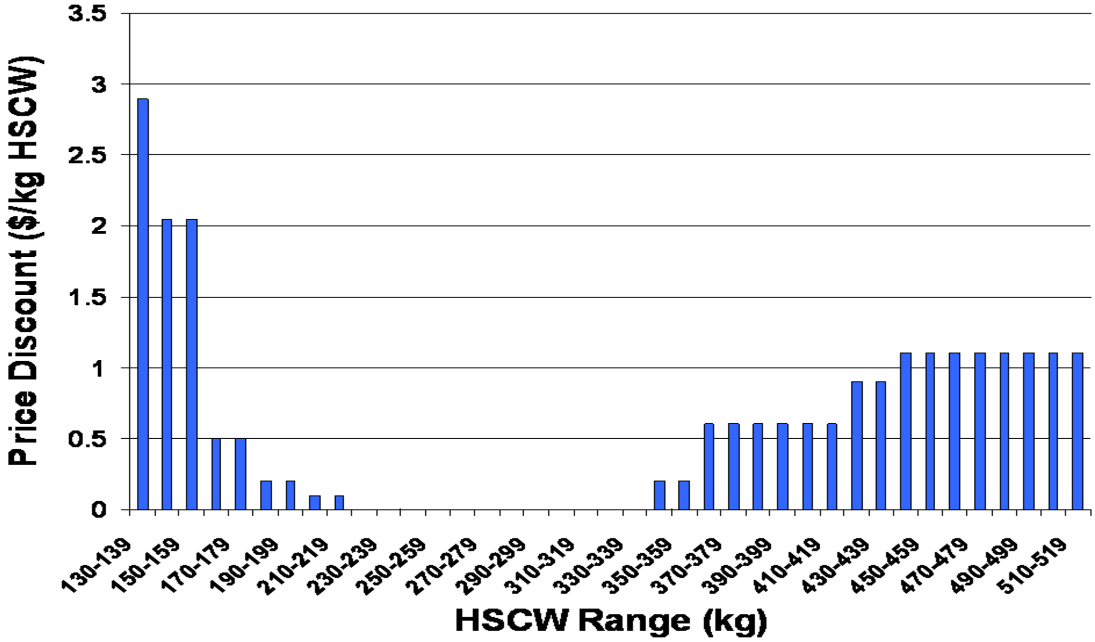

Figure 2. Price discount per kg HSCW ($/kg) applied to steer carcasses from dataset A for HSCW between 130 and 519 kg.

Figure 3 illustrates the distribution of HSCW in dataset A which contained 18,860 steer carcasses. A total of 3,284 steer carcasses failed to meet HSCW specifications which equates to 17.4% of those contained in dataset A. Most carcasses that missed specifications were toward the heavy end of the HSCW grid (15.4%).

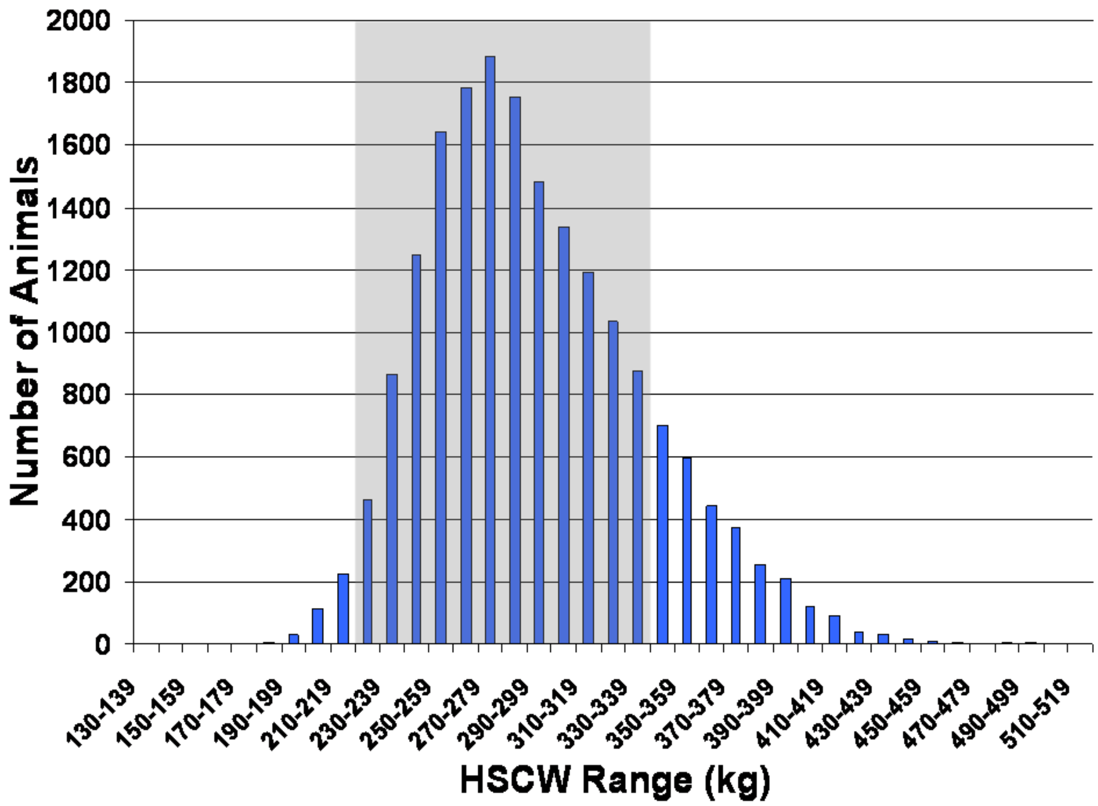

Figure 3. The distribution of HSCW (kg) of steers from dataset A. The HSCW range where no price discounts are incurred is shaded in grey.

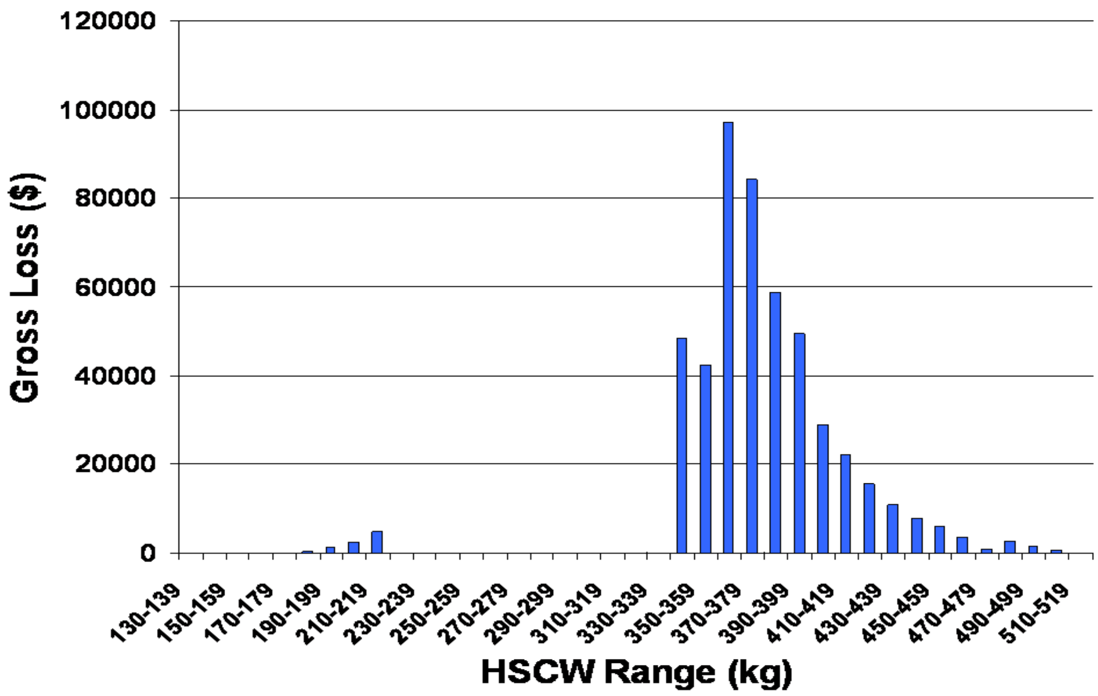

Figure 4. Gross loss ($) for steer carcasses in dataset A that failed to meet HSCW specifications.

The financial loss associated with 17.4% of steer carcases failing to meet HSCW specifications in dataset A is demonstrated in Figure 4. These losses equate to a total gross loss of $489,851 with 98.2% ($481,203) being attributable to over-weight carcasses. When averaged over those carcasses that did not meet specifications the losses were $149.16 per steer carcass. In comparison, when averaged across all 18,860 steer carcasses contained in dataset A these losses result in a $25.97 loss per carcass.

- Steer Rib Fat Results

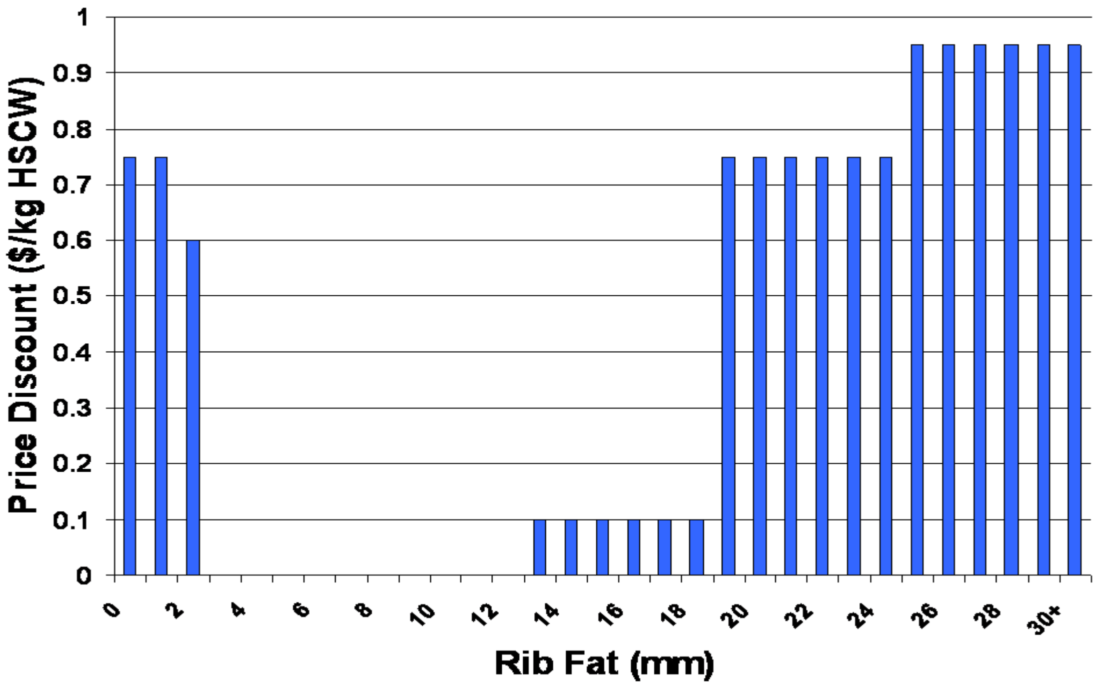

Figure 5. Price discount for rib fat depth (mm) of steer carcasses from dataset A applied on a per kg HSCW ($/kg) basis.

Figure 5 shows the price discounts associated with the P8 fat grid specifications (MSA graded market) relevant for steers from dataset A when converted to rib fat depths between 0 and 30$^+$ mm using Table 1. Note: the grid is an indicative grid supplied by a commercial abattoir. It is important to note that these discounts are given on a rib fat basis but applied on a HSCW basis [i.e., total discount = HSCW (kg) x Price Discount ($/kg HSCW)]. Rib fats in the range 3 to 12 mm receive no discount in price with discounts increasing in size as rib fat moves in each direction away from this ideal range. In contrast to the grid for HSCW shown in Figure 2, rib fats below 3 mm do not receive distinctly larger discounts than rib fats above 19 mm.

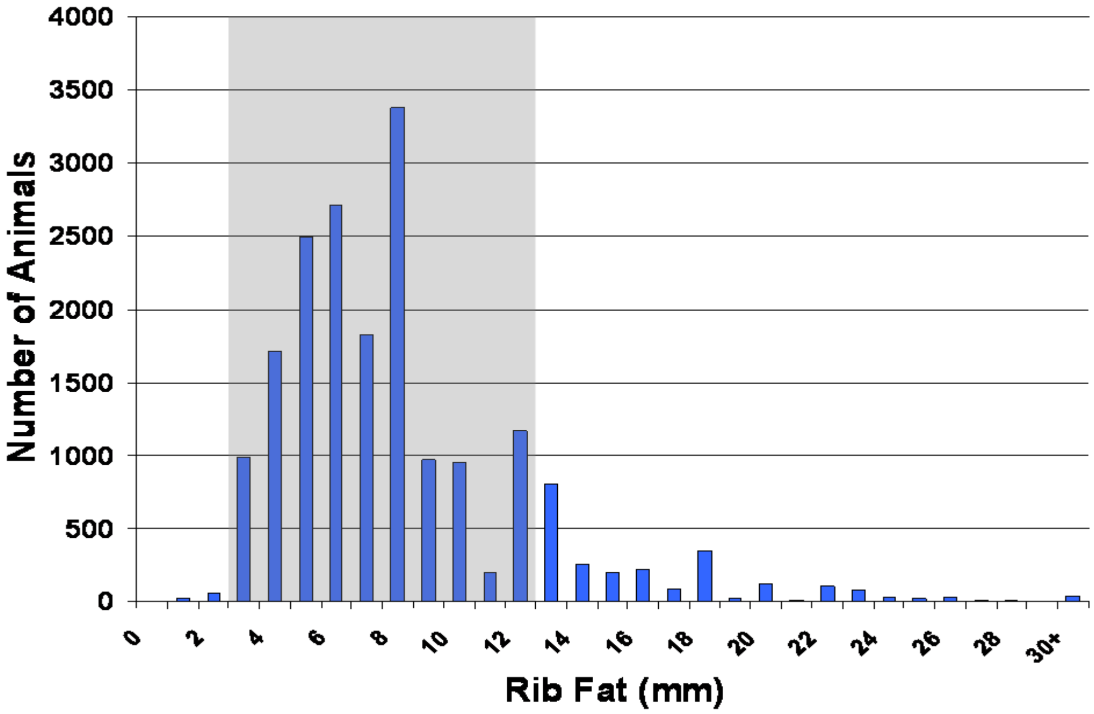

Figure 6. The distribution of rib fat (mm) of steers from dataset A. The rib fat range where no price discounts apply is shaded in grey.

Figure 6 illustrates the distribution of rib fat in dataset A which contained 18,860 steer carcasses. A total of 2,454 steer carcasses failed to meet rib fat specifications which equates to 13.0% of those contained in dataset A. Most carcasses that missed rib fat specifications were toward the fatter end of the rib fat grid (12.6%).

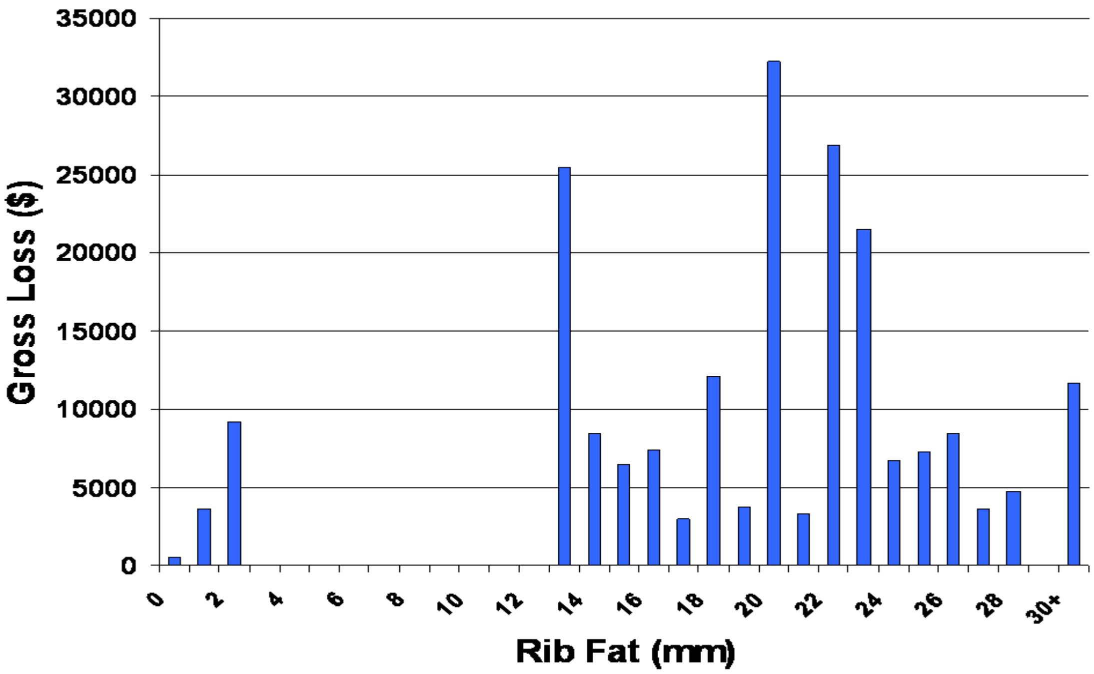

Figure 7. Gross loss ($) for steer carcasses in dataset A that failed to meet rib fat market specifications.

The financial loss associated with 13.0% of steer carcases in dataset A failing to meet rib fat specifications is demonstrated in Figure 7. These losses equate to a total gross loss of $206,287 with 93.6% ($193,040) being accounted for by over-fat carcasses. When averaged over those carcasses that did not meet specifications the losses were $84.06 per steer carcass. In comparison, when averaged across all 18,860 steer carcasses contained in dataset A these losses result in a $10.94 loss per carcass.

- Steer Combined Results

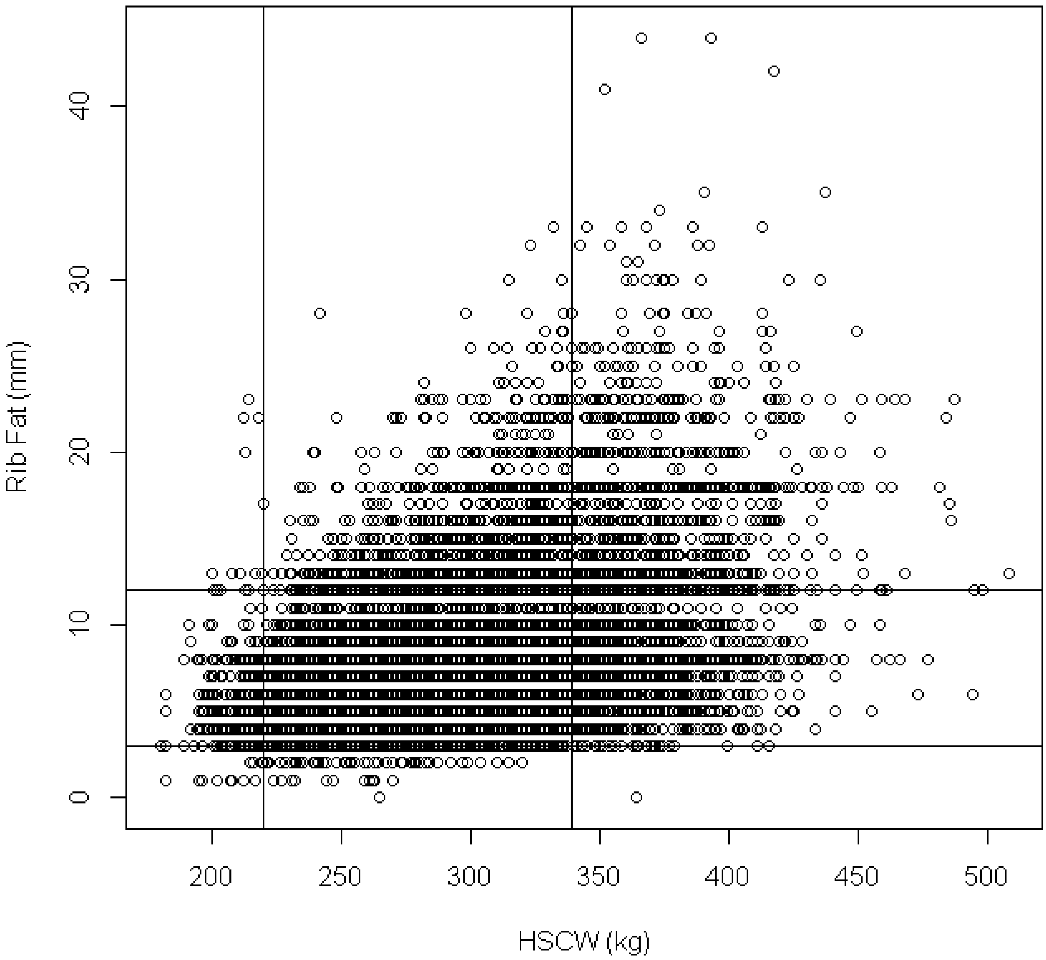

Figure 8. Relationship between HSCW (kg) and rib fat (mm) of steers in dataset A with vertical lines representing ideal HSCW specifications of 220 kg and 339 kg and horizontal lines representing ideal rib fat specifications of 3 mm and 12 mm.

Figure 8 illustrates that some steer carcasses in dataset A fail to comply with HSCW specifications while others fail to comply with rib fat specifications and others fail to comply with both HSCW and rib fat specifications. A total of 24.9% of the steer carcasses in dataset A fail to comply with HSCW or rib fat specifications or both. The resulting total gross loss is $634,767. When averaged over those carcasses that did not meet specifications the losses were $135.11 per steer carcass. In comparison, when averaged across all 18,860 steer carcasses contained in dataset A these losses were $33.66 per carcass. This result is in part due to some carcasses only failing to satisfy HSCW specifications while others only fail to satisfy rib fat specifications while others fail to satisfy both HSCW and rib fat specifications (Figure 8). Also contributing to this result is the price discounts received when failing to satisfy both HSCW and rib fat specifications are not simply the addition of discounts applied when failing to meet HSCW or rib fat specifications.

A summary of the percentage of carcasses out-of-specification (%), total gross loss ($), loss per steer carcass failing to meet specifications ($/carcass) and loss per carcass for all steers contained in dataset A ($/carcass) is reported in Table 2. The results in Table 2 also demonstrate that the losses due to failing to comply with HSCW or rib fat specifications are not the sum of their respective losses. In conjunction with Figure 8, these results also demonstrate that double counting of animals missing specifications occurs to some degree when analysing HSCW and rib fat independently. However, comparison of the losses per steer in dataset A demonstrates little difference between losses when HSCW and rib fat are analysed independently or in conjunction ($25.97 + $10.94 = $36.91 vs. $33.66). A similar result is seen when comparing the total gross loss ($489,851 + $206,287 = $696,138 vs. $634,766). In both cases there is a 9.7% upwards bias when analysing HSCW and rib fat independently. In contrast, if the losses are reported on a per animal failing specifications basis ($149.16 + $84.06 = $233.22 vs. $135.11) large quantities of bias are introduced (72.6%).

Table 2. The proportion of steer carcasses that failed to meet specifications, total gross loss ($), loss per steer carcass failing to meet specifications ($/carcass) and loss per steer carcass in dataset A ($/carcass) when HSCW and rib are analysed independently or in conjunction.

Item	HSCW[1]	Rib fat[1]	Both[1]
Out-of-specification (%)	17.4	13.0	24.9
Total Gross loss ($)	$489,851	$206,287	$634,767
Loss / Steer failing specifications ($/carcass)	$149.16	$84.06	$135.11
Loss / Steer contained in dataset A ($/carcass)	$25.97	$10.94	$33.66

[1]number of steer carcasses = 18,860

- Heifer HSCW Results

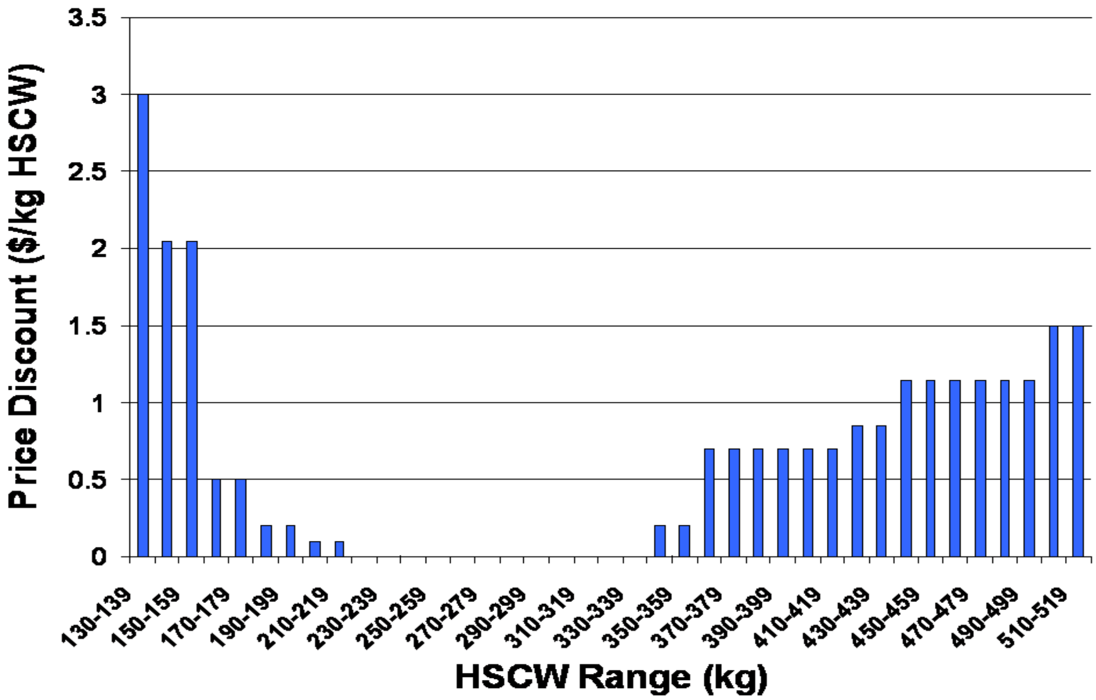

Figure 9. Price discount per kg HSCW ($/kg) applied to heifer carcasses from dataset A for HSCW between 130 and 519 kg.

Figure 9 shows the discount associated with HSCW (MSA graded market) between 130 and 519 kg in an indicative grid relevant for heifers in dataset A supplied by a commercial abattoir. As seen in Figure 2, HSCW in the range 220 to 339 kg receive no discount in price with discounts increasing in size as HSCW moves further in each direction away from this ideal range. In agreement with Figure 2 it is again quite evident that carcasses below 160 kg receive large discounts (>$2.00/kg HSCW). Also evident is discounts received by carcasses in the ranges 180-219kg and 340-359kg are relatively small ($0.10-$0.20/kg HSCW).

Figure 10 illustrates the distribution of HSCW in dataset A which contained 13,118 heifer carcasses. A total of 2,042 heifer carcasses failed to meet HSCW specifications which equates to 15.6% of those contained in dataset A. In contrast to Figure 3 most carcasses that missed specifications were toward the lighter end of the HSCW grid (13.4%).

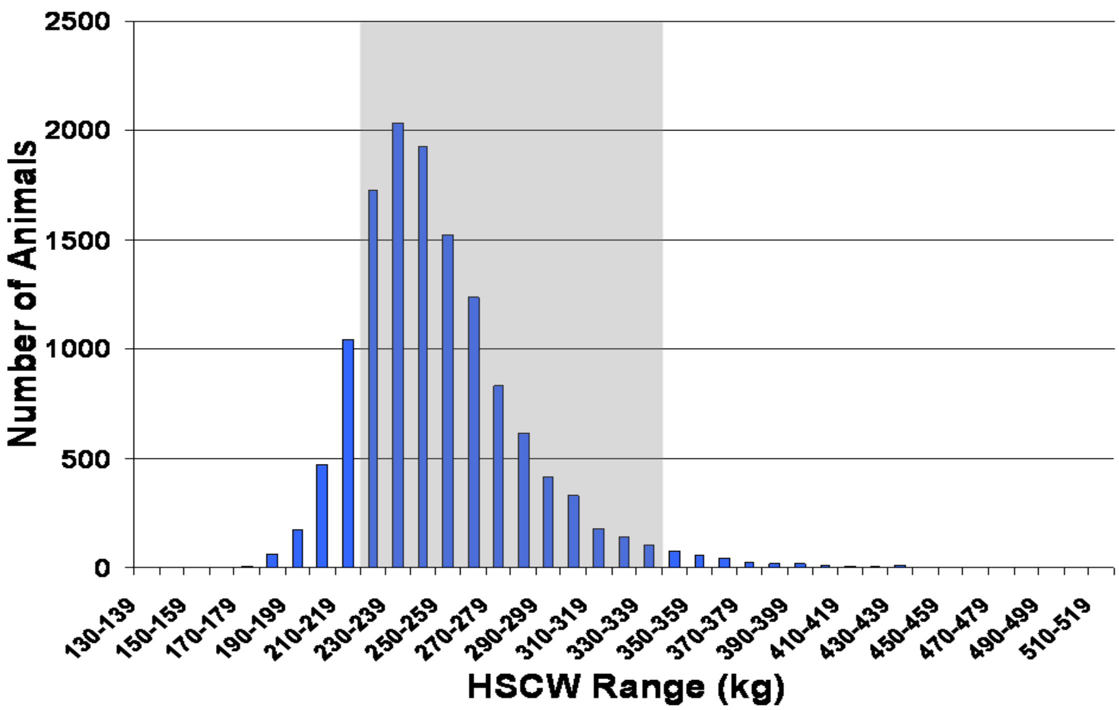

Figure 10. The HSCW (kg) distribution of heifers from dataset A. The HSCW range where no price discounts apply is shaded in grey.

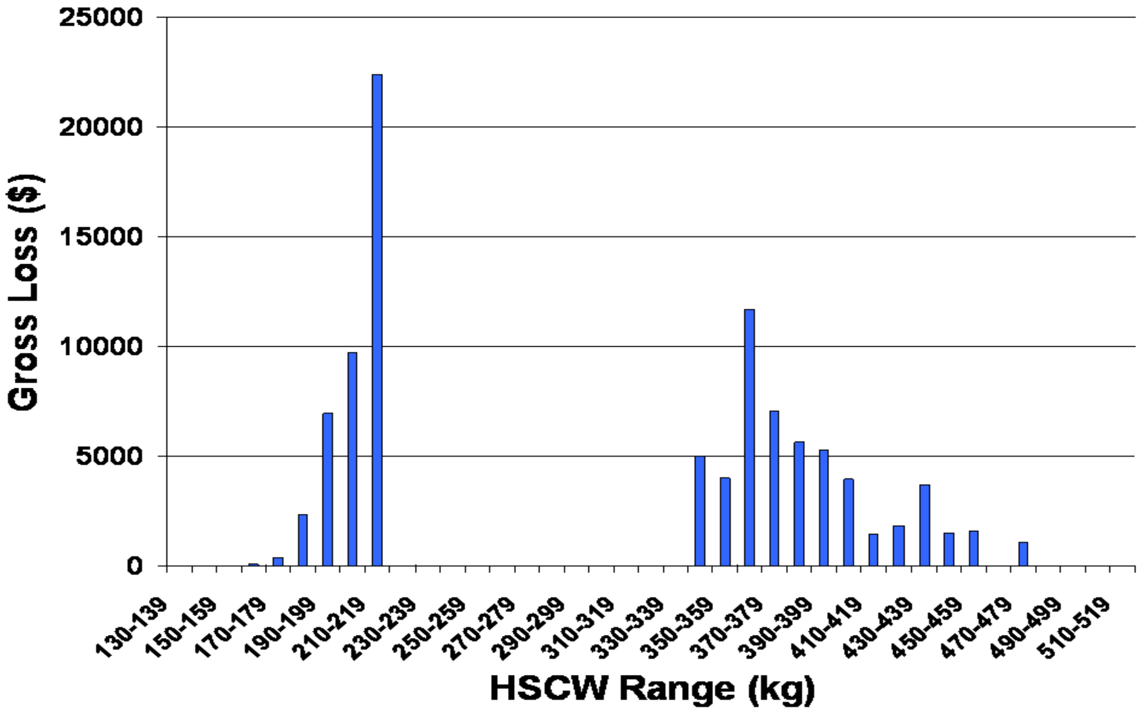

Figure 11. Gross loss ($) for heifer carcasses in dataset A that failed to meet HSCW specifications.

The financial loss associated with 15.6% of heifer carcases contained in dataset A failing to meet HSCW specifications is demonstrated in Figure 11. These losses equate to a total gross loss of $95,486. Although the majority of carcasses missed specifications for being too light these carcasses only accounted for 43.7% ($41,753) of the total gross losses. This disparity is due to those carcasses that missed specifications for being too light being contained in the first category to the left of the ideal range (Figure 9) which is penalised $0.10/kg HSCW. When averaged over those carcasses that did not meet specifications the losses were $46.76 per heifer carcass. In comparison, when averaged across all 13,118 heifer carcasses in dataset A these losses result in a $7.28 loss per carcass.

- Heifer Rib Fat Results

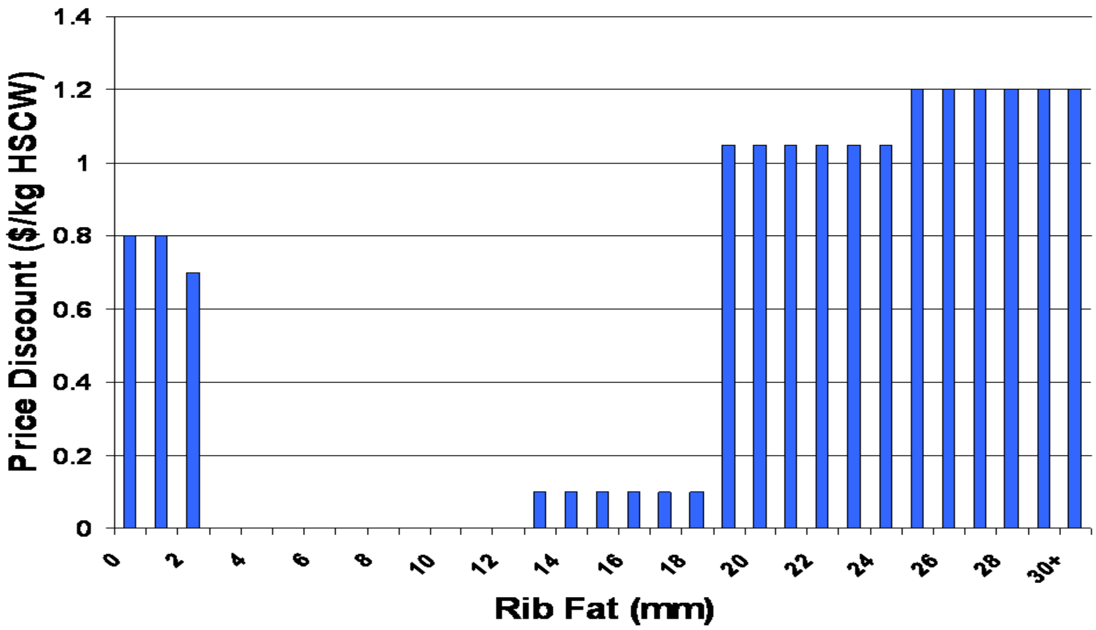

Figure 12. Price discounts for rib fat depth (mm) of heifers from dataset A applied on a per kg HSCW ($/kg) basis.

Figure 12 shows the price discounts associated with the P8 fat grid specifications (MSA graded market) relevant for heifers from dataset A when converted to rib fat depths between 0 and 30^+ mm using Table 1. Note: the grid is an indicative grid supplied by a commercial abattoir. It is important to note that these discounts are given on a rib fat basis but applied on a HSCW basis. Rib fats in the range 3 to 12 mm receive no discount in price with discounts increasing in size as rib fat moves further in each direction away from this ideal range. In contrast to Figures 2 and 9 rib fats below 3 mm do not receive distinctly larger discounts than rib fats above 19 mm. These discounts are similar in pattern to those contained in Figure 5 however they are $0.05-$0.10 higher when rib fat is below 2 mm and $0.25-$0.30 higher when rib fat is above 19 mm.

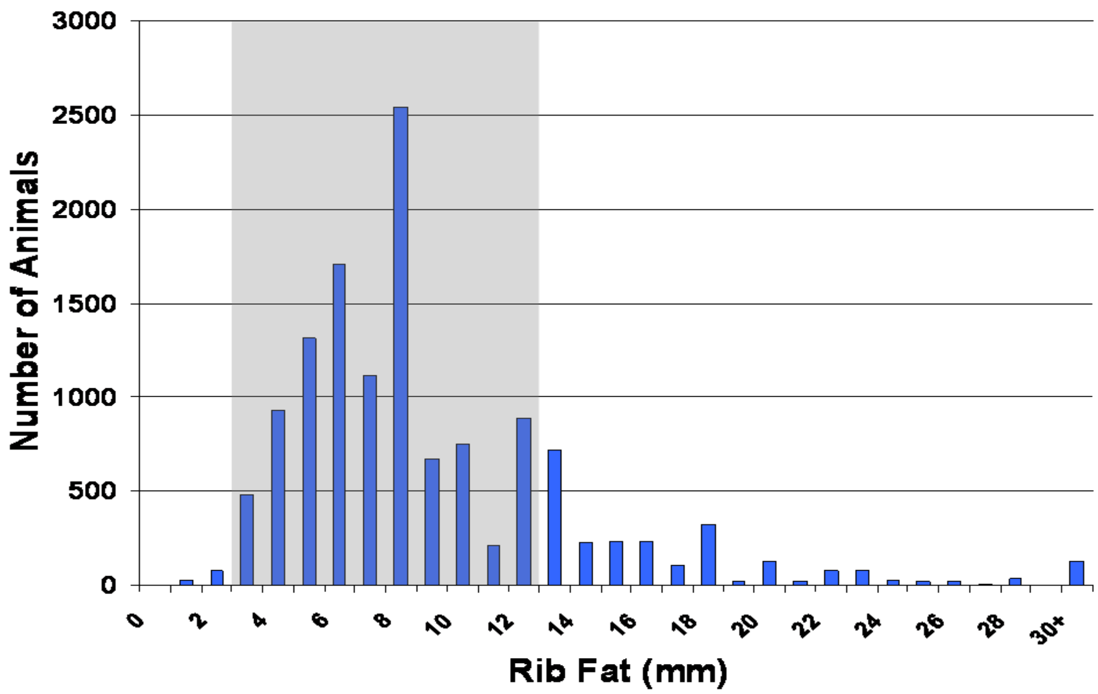

Figure 13. The distribution of rib fat (mm) of heifers from dataset A. The rib fat range where no price discounts apply is shaded in grey.

Figure 13 illustrates the distribution of rib fats in dataset A which contained 13,118 heifer carcasses. A total of 2,502 heifer carcasses failed to meet rib fat specifications which equates to 19.1% of those contained in dataset A. Most carcasses that missed rib fat specifications were toward the fatter end of the rib fat grid (18.3%).

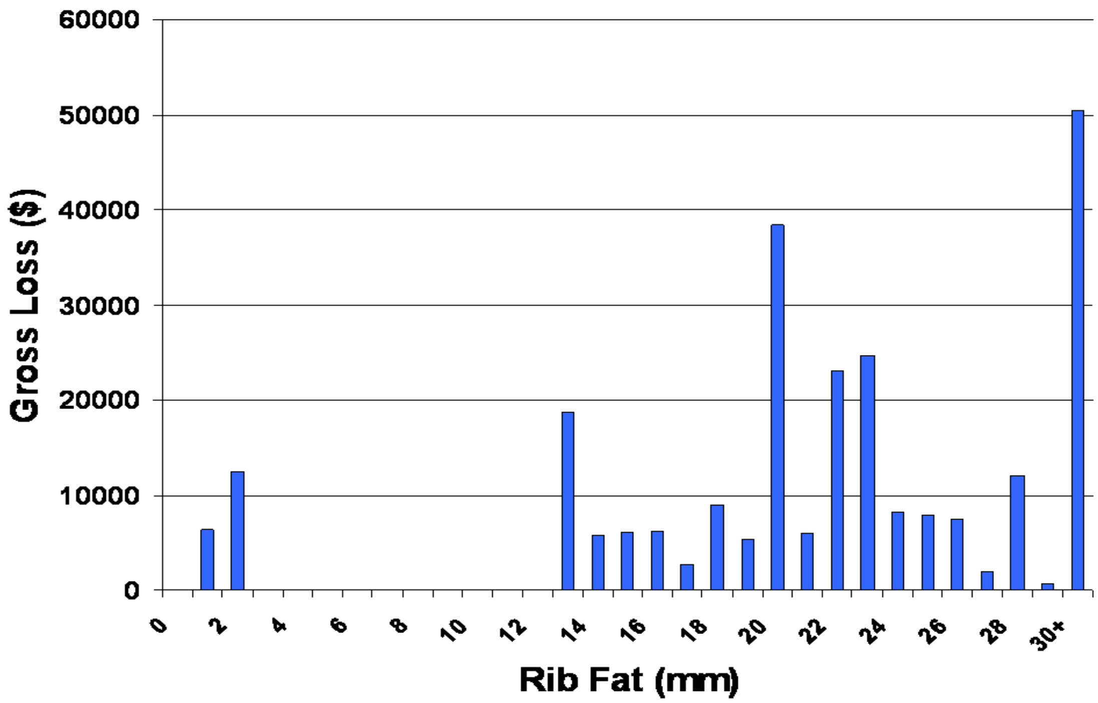

Figure 14. Gross loss ($) for heifer carcasses in dataset A that failed to meet rib fat market specifications.

The financial loss associated with 19.1% of heifer carcases in dataset A failing to meet rib fat specifications is demonstrated in Figure 14. These losses equate to a total gross loss of $253,981 with 92.5% ($235,039) being accounted for by over-fat carcasses. When averaged over those carcasses that did not meet specifications the losses were $101.51 per heifer carcass. In comparison, when averaged across all 13,118 heifer carcasses contained in dataset A these losses result in a $19.36 loss per carcass.

- Heifer Combined Results

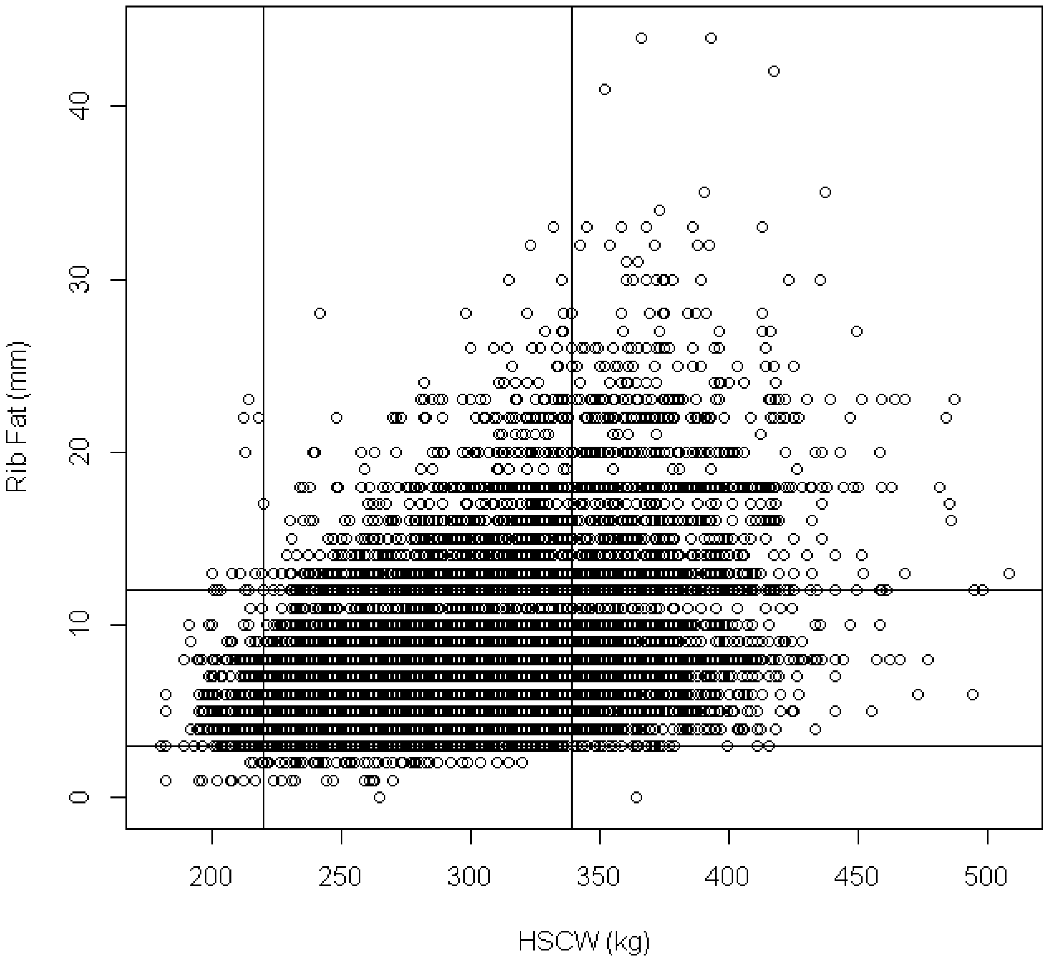

Figure 15. Relationship between HSCW (kg) and rib fat (mm) of heifers in dataset A with vertical lines representing ideal HSCW specifications of 220 kg and 339 kg and horizontal lines representing ideal rib fat specifications of 3 mm and 12 mm.

Figure 15 illustrates that some heifer carcasses in dataset A fail to comply with HSCW specifications while others fail to comply with rib fat specifications and others fail to comply with both HSCW and rib fat specifications. A total of 32.1% of the heifer carcasses in dataset A fail to comply with HSCW or rib fat specifications or both. The resulting total gross loss is $325,619. When averaged over those carcasses that did not meet specifications the losses were $77.29 per heifer carcass. In comparison, when averaged across all 13,118 heifer carcasses contained in dataset A these losses were $24.82 per carcass. In agreement with Figure 8, the non-compliance rates in Figure 15 are a result, in part, of some carcasses only failing to satisfy HSCW specifications while others only fail to satisfy rib fat specifications while others fail to satisfy both HSCW and rib fat specifications. Also contributing to this result is the price discounts received when failing to satisfy both HSCW and rib fat specifications are not simply the addition of discounts applied when failing to meet HSCW or rib fat specifications.

A summary of the percentage of carcasses out-of-specification (%), total gross loss ($), loss per heifer carcass failing to meet specifications ($/carcass) and loss per carcass for all heifer carcasses in dataset A ($/carcass) is reported in Table 3. The results in Table 3 support Table 2, in that, they demonstrate losses due to failing to comply with HSCW or rib fat specifications are not additive. When used in conjunction with Figure 15, it is again evident that double counting of animals missing specifications occurs to some extent when analysing HSCW and rib fat independently. The results in Table 3 also support those presented in Table 2, in that, comparison of the losses per heifer in dataset A demonstrates little difference between losses when HSCW and rib fat are analysed independently or in conjunction ($7.28 + $19.36 = $26.64 vs. $24.82). A similar result is seen when comparing the total gross loss ($95,486 + $253,981 = $349,467 vs. $325,619). In both cases there is a 7.3% upward bias when analysing HSCW and rib fat independently. In contrast, if the losses are reported on a per animal failing specifications basis ($46.76 + $101.51 = $148.27 vs. $77.29) large quantities of bias are introduced (91.8%) which is higher than the bias presented in Table 2.

Table 3. The proportion of heifer carcasses that failed to meet specifications, total gross loss ($), loss per heifer carcass failing to meet specifications ($/carcass) and loss per heifer carcass in dataset A ($/carcass) when HSCW and rib are analysed independently or in conjunction.

Item	HSCW[1]	Rib fat[1]	Both[1]
Out-of-specifications (%)	15.6	19.1	32.1
Total Gross loss ($)	$95,486	$253,981	$325,619
Loss / Steer failing specifications ($/carcass)	$46.76	$101.51	$77.29
Loss / Steer contained in dataset A ($/carcass)	$7.28	$19.36	$24.82

[1]number of heifer carcasses = 13,118

3.3.1.2 Dataset B

- Steer HSCW Results

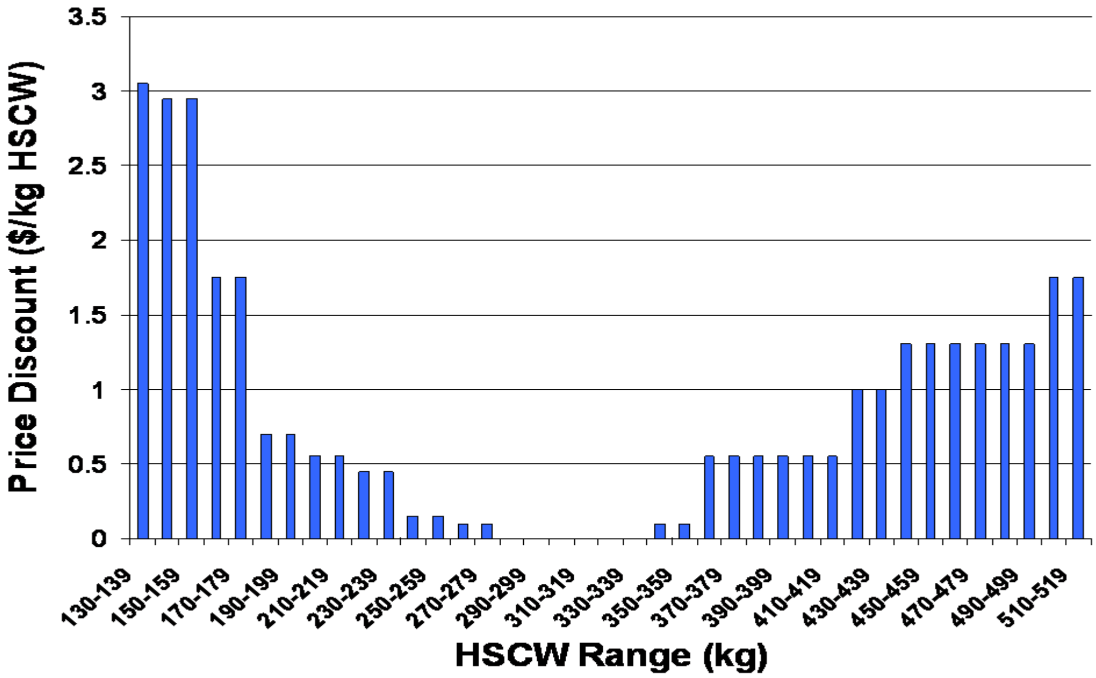

Figure 16. Price discount per kg HSCW ($/kg) applied to steer carcasses from dataset B for HSCW between 130 and 519 kg.

Figure 16 shows the discount associated with HSCW (MSA graded market) between 130 and 519 kg and in an indicative grid relevant for steers from dataset B supplied by a commercial abattoir. Comparison with the price discounts displayed in Figure 2 reveals this carcass grid is much more demanding in terms of the smaller HSCW range where no discounts apply. The HSCW range where no discounts are applied is between 280 to 339 kg with discounts increasing in size as HSCW moves further in each direction away from this ideal range. It is again quite evident that carcasses below 160 kg receive large discounts ($2.50/kg HSCW). Similar to Figure 2, the discounts received by carcasses in Figure 16 close to the ideal range (e.g. 240-259 kg and 340-359 kg) are relatively small ($0.10-$0.20/kg HSCW). In contrast to Figure 2, Figure 16 contains a larger number of price discount graduations as HSCW moves away from the ideal range.

Figure 17 illustrates the distribution of HSCW in dataset B which contained 25,114 steer carcasses. The bimodal distribution seen in Figure 17 suggests steers carcasses in this dataset may have been destined for two markets with different specifications. Further examination of the dataset revealed each carcass was branded with the brands being associated with the peaks of the bimodal distribution evident in Figure 17. The data were subsequently divided into two brand groups with approximately equal representation found for each brand. Brand 1 was found to have the strongest agreement with the carcass specifications supplied by the commercial abattoir for this dataset. For the purposes of this study, data on non-compliance rates to carcass specifications and the associated financial losses will be presented for brand 1 only.

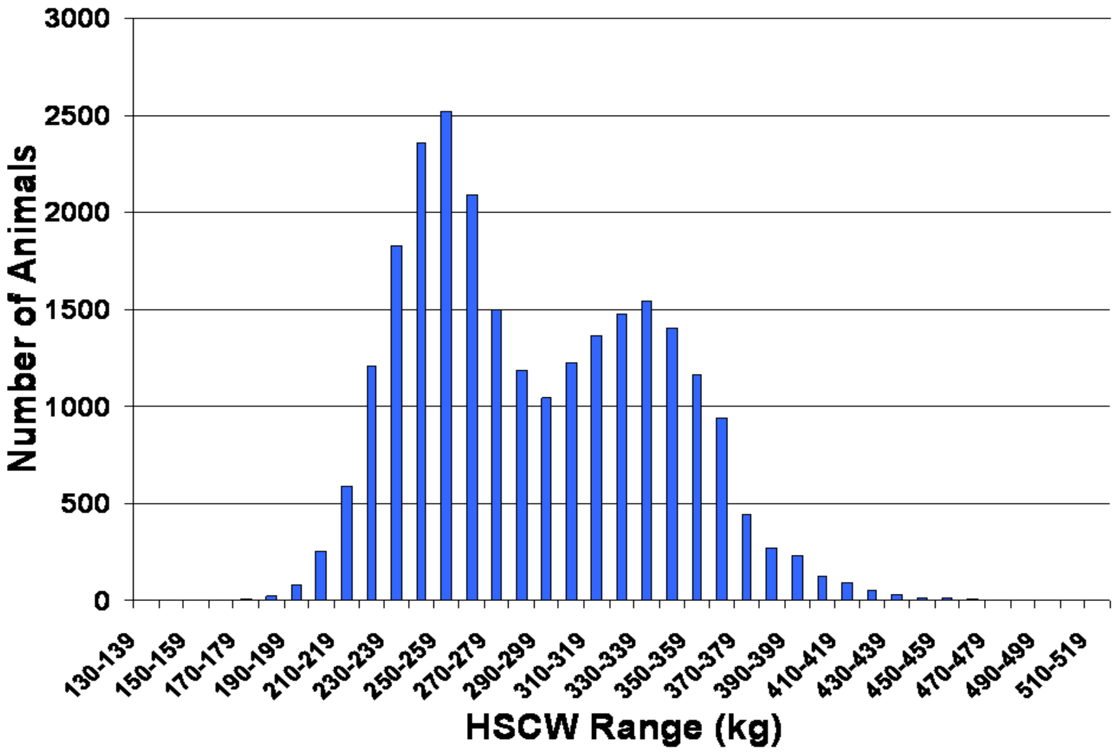

Figure 17. The distribution of HSCW (kg) of steers from dataset B.

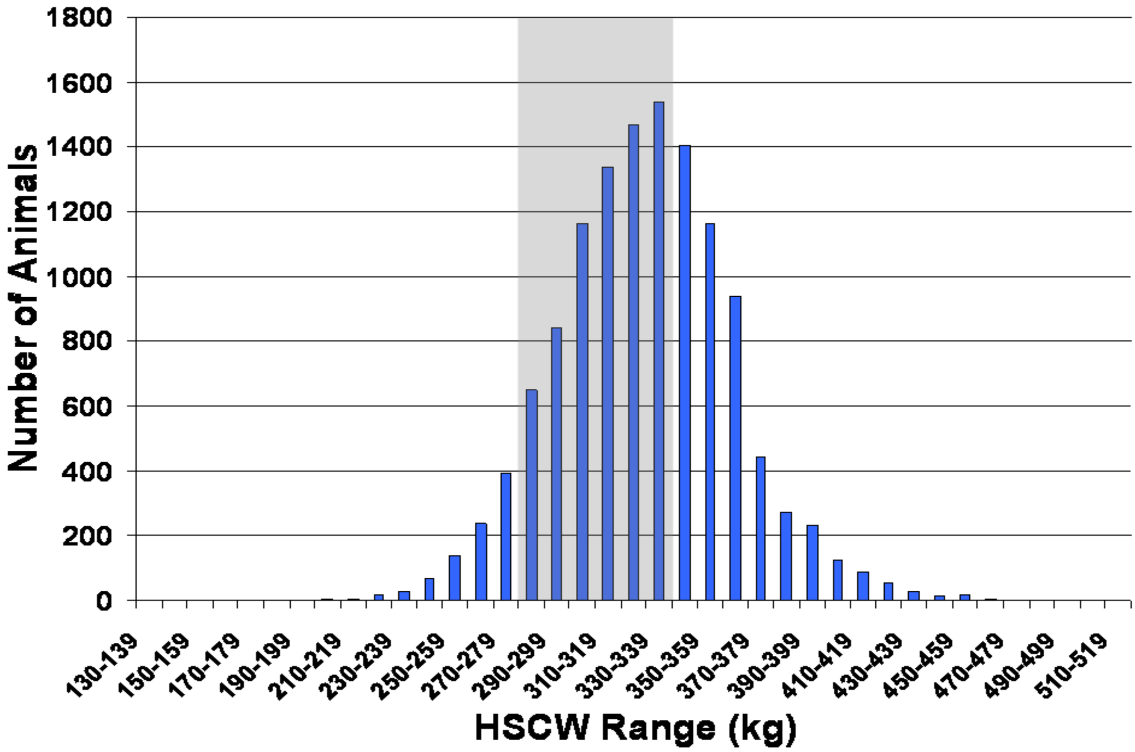

Figure 18. The distribution of HSCW (kg) of steers from brand 1 contained in dataset B. The HSCW range where no price discounts apply is shaded in grey.

Figure 18 illustrates the distribution of HSCW in brand 1 from dataset B which contained 12,694 steer carcasses. A total of 5,689 steer carcasses failed to meet

HSCW specifications which equates to 44.8% of those contained in brand 1 from dataset 2. This proportion of carcasses failing to meet HSCW specifications is substantially larger than those proportions demonstrated in Figures 3 and 10 for steers and heifers in dataset A. Most carcasses that missed specifications were toward the heavy end of the HSCW grid (37.8%).

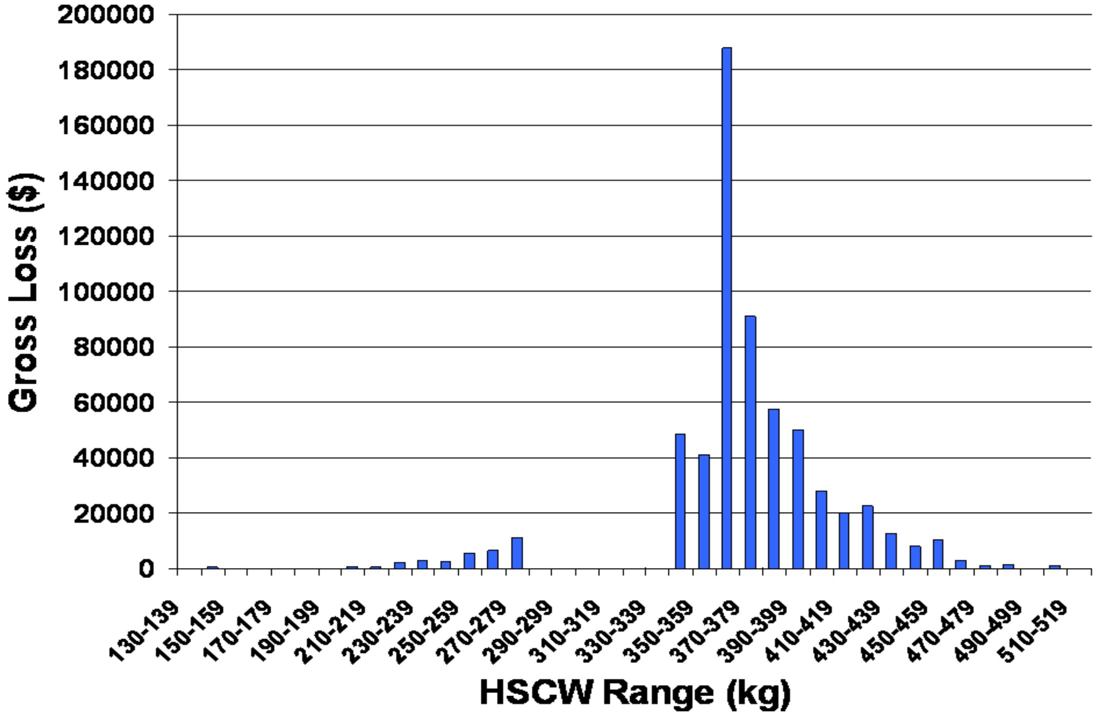

Figure 19. Gross loss ($) for steer carcasses from brand 1 in dataset B that failed to meet HSCW specifications.

The financial loss associated with 44.8% of steer carcases failing to meet HSCW specifications in dataset B is demonstrated in Figure 19. These losses equate to a total gross loss of $615,826 with 94.9% ($584,422) being attributable to over-weight carcasses. When averaged over those carcasses that did not meet specifications the losses were $108.25 per steer carcass. In comparison, when averaged across all 12,694 steer carcasses contained in brand 1 from dataset B these losses result in a $48.51 loss per carcass. The loss, as measured by per carcass in the dataset, is much greater than that found for steers and heifers in dataset A.

- Steer Rib Fat Results

Figure 20 shows the price discounts associated with the P8 fat grid specifications (MSA graded market) relevant for steers from dataset B when converted to rib fat depths between 0 and 30^+ mm using Table 1. Note: the grid is an indicative grid supplied by a commercial abattoir. It is important to note that these discounts are given on a rib fat basis but applied on a HSCW basis. This grid follows a similar pattern to that evident in Figure 5 in that rib fat in the range 3 to 12 mm receives no discount in price with discounts increasing in size as rib fat moves further in each direction away from this ideal range. However, the discounts received for rib fats above 18 mm are $0.20-$0.25/kg HSCW higher in Figure 20.

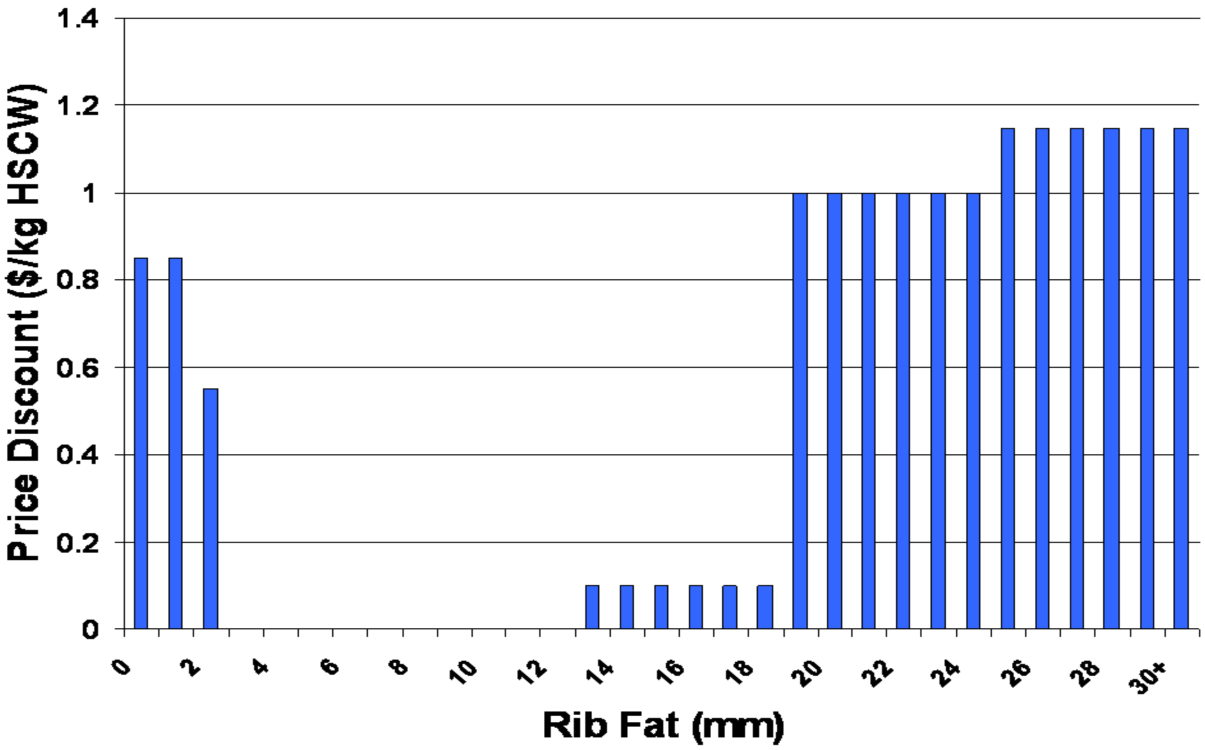

Figure 20. Price discount for rib fat depth (mm) of steer carcasses from brand 1 in dataset B applied on a per kg HSCW ($/kg) basis.

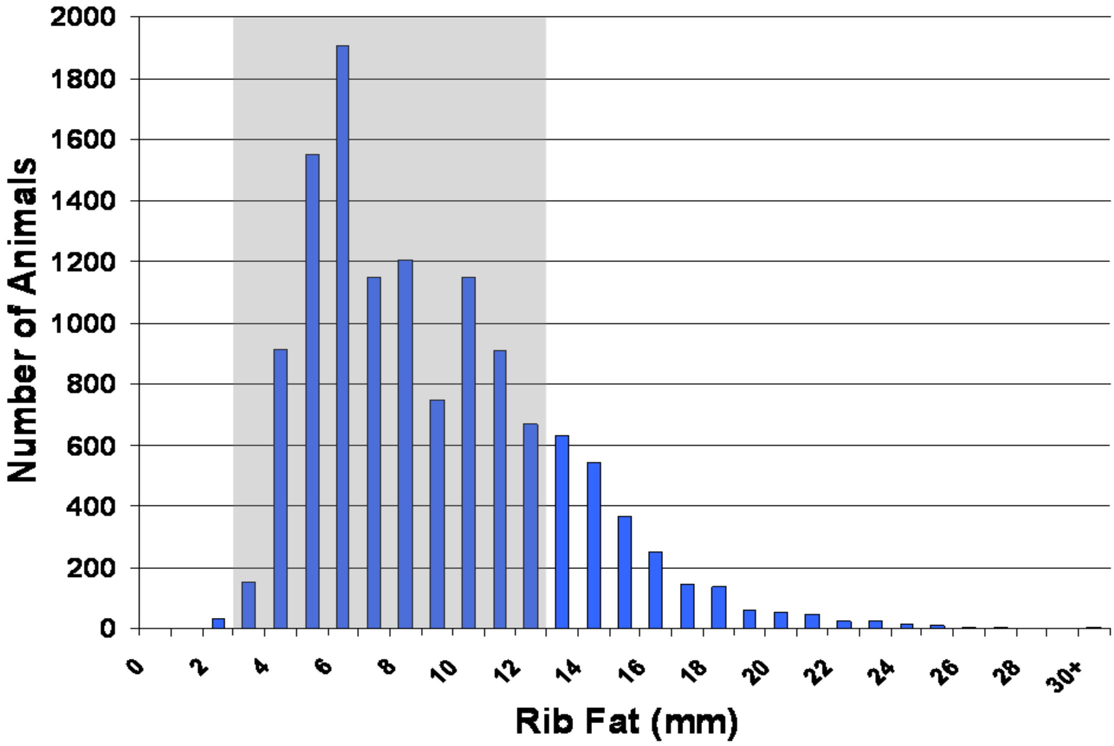

Figure 21. The distribution of rib fat (mm) of steers from brand 1 in dataset B. The rib fat range where no price discounts apply is shaded in grey.

Figure 21 illustrates the distribution of rib fat in brand 1 from dataset B which contained 12,694 steer carcasses. A total of 2,350 steer carcasses failed to meet rib fat specifications which equates to 18.5% of those contained in brand 1 from dataset B. Most carcasses that missed rib fat specifications were toward the fatter end of the rib fat grid (18.2%).

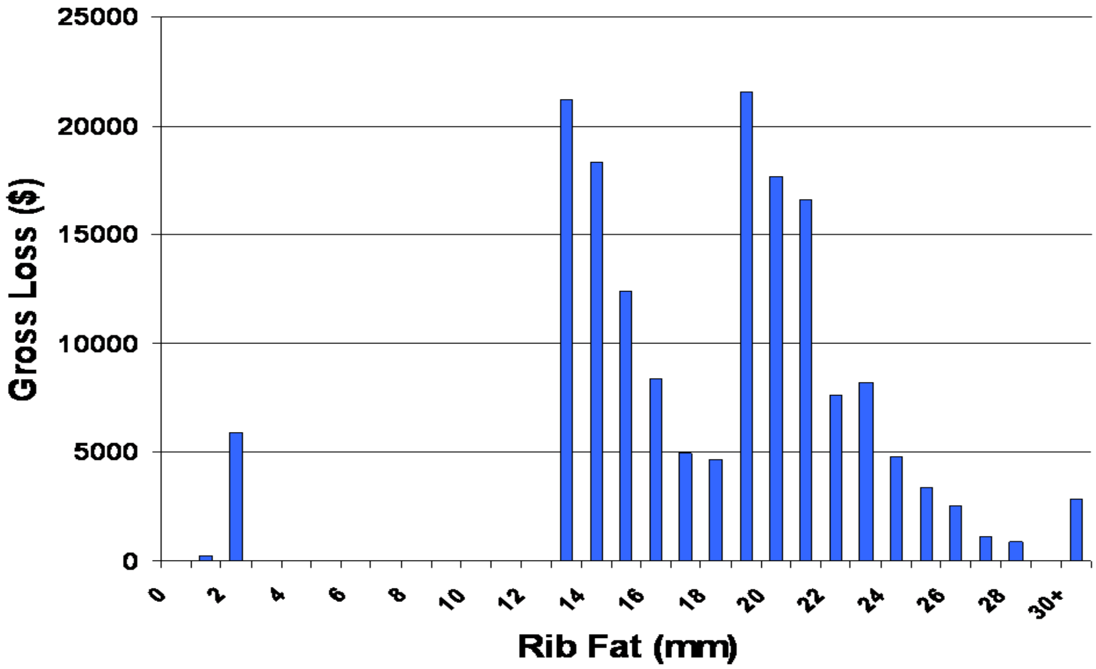

Figure 22. Gross loss ($) for steer carcasses from brand 1 in dataset B that failed to meet rib fat market specifications.

The financial loss associated with 18.5% of steer carcases contained in brand 1 from dataset B failing to meet rib fat specifications is demonstrated in Figure 22. These losses equate to a total gross loss of $163,438 with 96.2% ($157,300) being accounted for by over-fat carcasses. When averaged over those carcasses that did not meet specifications the losses were $69.55 per steer carcass. In comparison, when averaged across all 12,694 steer carcasses in brand 1 from dataset B these losses result in a $12.88 loss per carcass.

- Steer Combined Results

Figure 23 illustrates that some steer carcasses in brand 1 from dataset B fail to comply with HSCW specifications while others fail to comply with rib fat specifications and others fail to comply with both HSCW and rib fat specifications. A total of 53.9% of the steer carcasses in brand 1 from dataset B fail to comply with HSCW or rib fat specifications or both. The resulting total gross loss is $747,885. When averaged over those carcasses that did not meet specifications the losses were $109.21 per steer carcass. In comparison, when averaged across all 12,694 steer carcasses contained in brand 1 from dataset B these losses were $58.92 per carcass. Again this result is in part due to some carcasses only failing to satisfy HSCW specifications while others only fail to satisfy rib fat specifications and others fail to satisfy both HSCW and rib fat specifications.

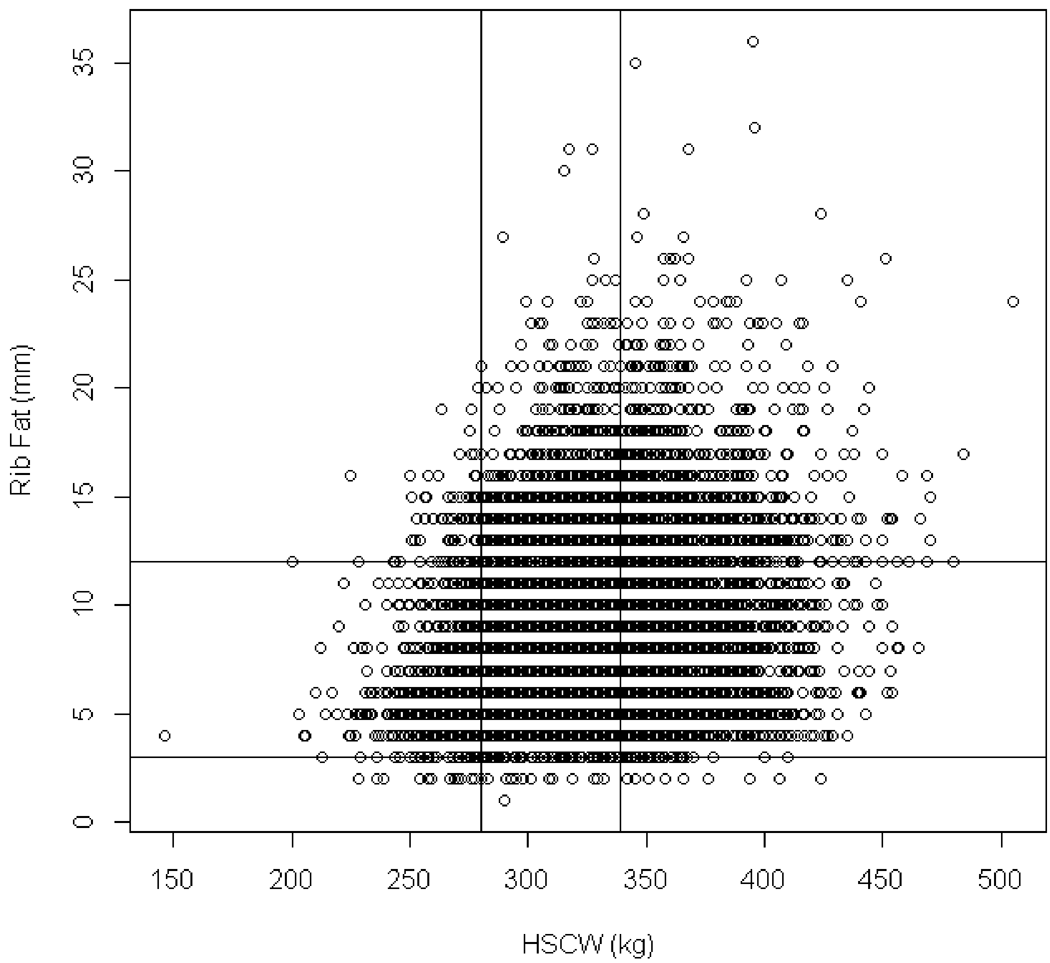

Figure 23. Relationship between HSCW (kg) and rib fat (mm) of steers in brand 1 from dataset B with vertical lines representing ideal HSCW specifications of 280 kg and 339 kg and horizontal lines representing ideal rib fat specifications of 3 mm and 12 mm.

A summary of the percentage of carcasses out-of-specification (%), total gross loss ($), loss per steer carcass failing to meet specifications ($/carcass) and loss per carcass for all steers contained in brand 1 from dataset B ($/carcass) is reported in Table 4. The results in Table 4 support the findings in Tables 2 and 3 discussed above in relation to losses due to failing to comply with HSCW or rib fat specifications not being additive and that some double counting of carcasses that miss specifications occurs analysing HSCW and rib fat independently. However, again the comparison of the losses per steer in brand 1 from dataset B demonstrate little difference between losses when HSCW and rib fat are analysed independently or in conjunction ($48.51 + $12.88 = $61.39 vs. $58.92). A similar result is seen when comparing the total gross loss ($615,826 + $163,438 = $779,263 vs. $747,885). Both approaches result in a 4.2% upward bias when analysing HSCW and rib fat independently. In contrast, if the losses are reported on a per animal failing specifications basis ($108.25 + $69.55 = $177.80 vs. $109.21) large quantities of bias are introduced (62.8%).

Table 4. The proportion of steer carcasses that failed to meet specifications, total gross loss ($), loss per steer carcass failing to meet specifications ($/carcass) and loss per steer carcass in brand 1 from dataset B ($/carcass) when HSCW and rib are analysed independently or in conjunction.

Item	HSCW[1]	Rib fat[1]	Both[1]
Out-of-specification (%)	44.8	18.5	53.9
Total Gross loss ($)	$615,826	$163,438	$747,885
Loss / Steer failing specifications ($/carcass)	$108.25	$69.55	$109.21
Loss / Steer contained in dataset A ($/carcass)	$48.51	$12.88	$58.92

[1]number of steer carcasses = 12,694

- Heifer HSCW Results

Figure 24 shows the discount associated with HSCW (MSA graded market) between 130 and 519 kg in an indicative grid relevant for heifers from dataset B supplied by a commercial abattoir. The pattern evident in Figure 24 reflects that seen in Figure 16 where no discounts are applied between 280 and 339 kg HSCW and discounts increase in size as HSCW moves further away from this ideal range in each direction. These price discounts are also more demanding in terms of the smaller HSCW range where no discounts apply when compared to Figure 9. Carcasses below 160 kg receive substantially larger discounts than those presented in Figures 2, 9 and 16 (>$3.00/kg HSCW). Similar to Figure 9, the discounts received by carcasses in Figure 24 close to the ideal range (e.g. 240-259 kg and 340-359 kg) are relatively small ($0.10-$0.20/kg HSCW). In contrast to Figure 9, Figure 24 contains a larger number of price discount graduations as HSCW moves away from the ideal range.

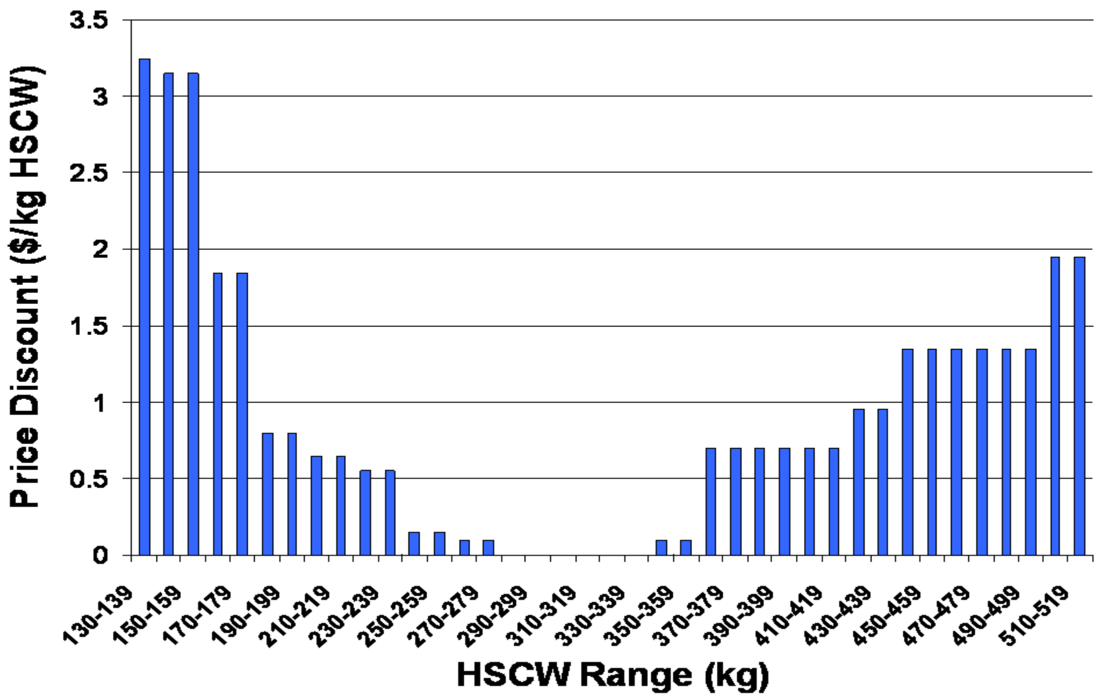

Figure 24. Price discount per kg HSCW ($/kg) applied to heifer carcasses from dataset B for HSCW between 130 and 519 kg.

Figure 25 illustrates the distribution of HSCW in dataset B which contained 20,848 heifer carcasses. A total of 18,393 heifer carcasses failed to meet HSCW specifications which equates to 88.2% of those contained in dataset B. This proportion of carcasses failing to meet HSCW specifications is substantially larger than those proportions demonstrated in Figures 3 and 10 for steers and heifers in dataset A and those demonstrated in Figure 18 for steers from brand 1 in dataset B. This result is higher than expected and could be an indication that the carcass specifications shown in Figure 24 are not relevant for the heifer carcasses in dataset B. In agreement with Figure 10 and in contrast to Figures 3 and 18, most carcasses that missed specifications were toward the heavy end of the HSCW grid (85.7%).

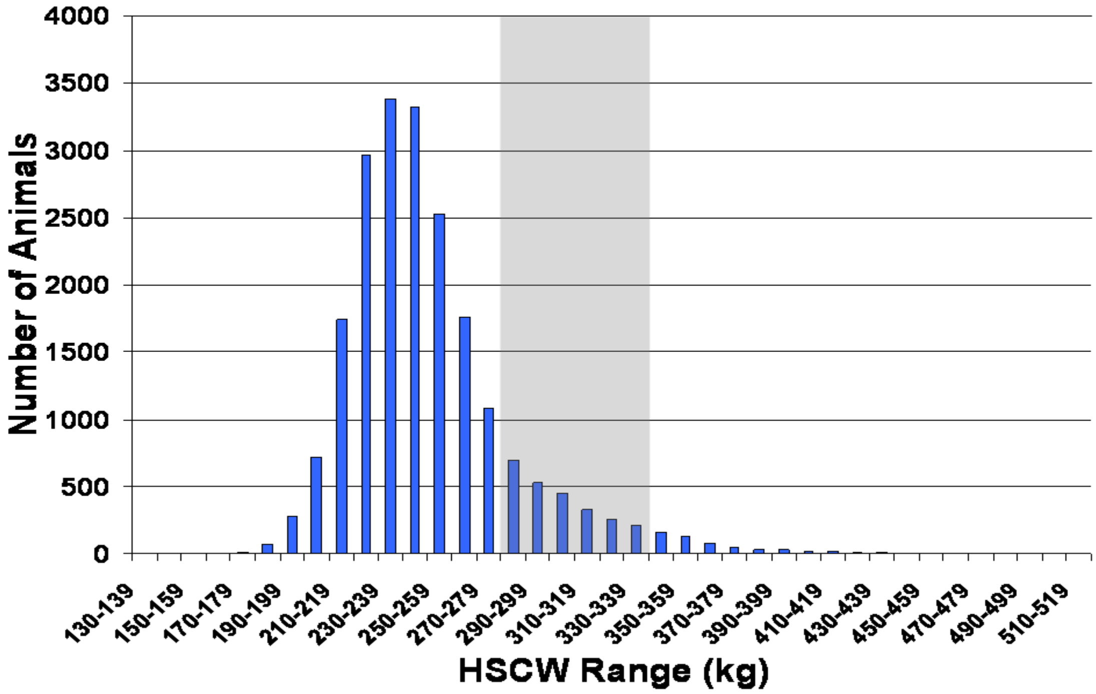

Figure 25. The distribution of HSCW (kg) of heifers from dataset B. The HSCW range where no price discounts are incurred is shaded in grey.

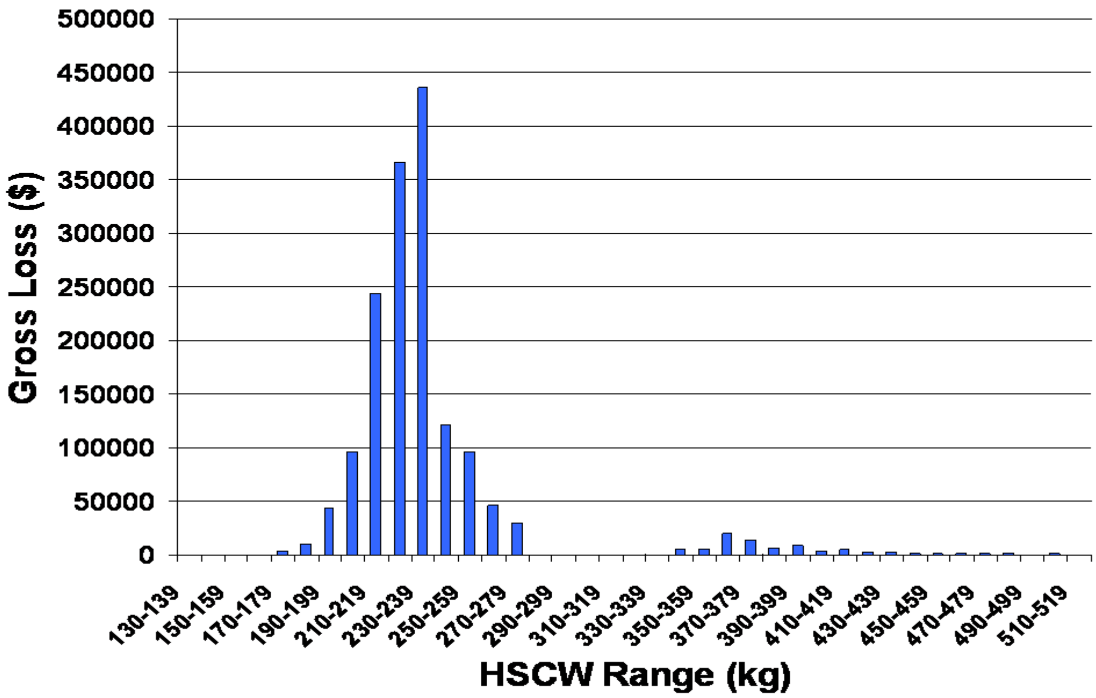

Figure 26. Gross loss ($) for heifer carcasses in dataset B that failed to meet HSCW specifications.

The financial loss associated with 88.2% of heifer carcasses contained in dataset B failing to meet HSCW specifications is demonstrated in Figure 26. These losses equate to a total gross loss of $1,575,266 with 95.0% ($1,496,632) being attributable to under-weight carcasses. This result contrasts with that seen in Figures 4 and 19 where the majority of losses were due to over-weight carcasses. When averaged over those carcasses that did not meet specifications the losses were $85.64 per heifer carcass. This loss per heifer carcass is lower that the losses found for steer carcasses in both datasets. In comparison, when averaged across all 20,848 heifer carcasses contained in dataset B these losses result in a $75.56 loss per carcass. The loss, as measured by per carcass in the dataset, is the largest found in either dataset in this study.

- Heifer Rib Fat Results

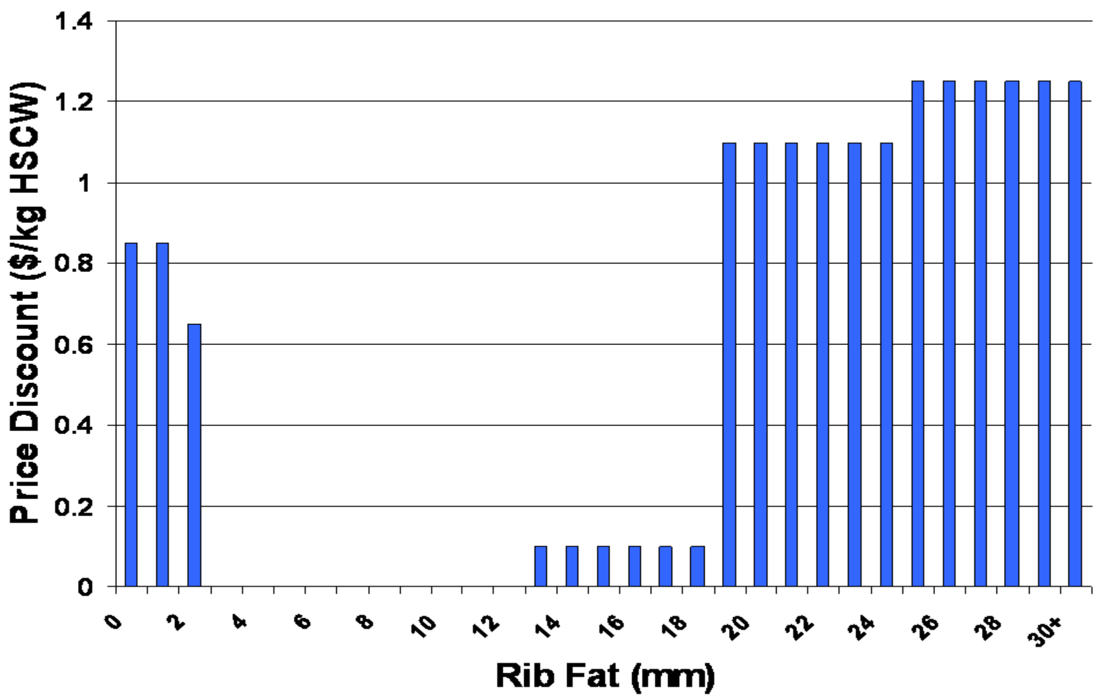

Figure 27. Price discount for rib fat depth (mm) of heifer carcasses from dataset B applied on a per kg HSCW ($/kg) basis.

Figure 27 shows the price discounts associated with the P8 fat grid specifications (MSA graded market) relevant for heifers from dataset B when converted to rib fat depths between 0 and 30^+ mm using Table 1. Note: the grid is an indicative grid supplied by a commercial abattoir. It is important to note that these discounts are given on a rib fat basis but applied on a HSCW basis. Reflecting Figures 6, 12 and 20 rib fats in the range 3 to 12 mm receive no discount in price with discounts increasing in size as rib fat moves in each direction away from this ideal range. In contrast to the grid for HSCW shown in Figure 20, rib fats below 3 mm do not receive distinctly larger discounts than rib fats above 19 mm. These discounts are similar in pattern to those contained in Figure 20 however they are $0.10 higher when rib fat is 2 mm but in contrast to the grid for dataset A only $0.10 higher when rib fat is above 19 mm.

Figure 28 illustrates the distribution of rib fat in dataset B which contained 20,848 heifer carcasses. A total of 2,986 heifer carcasses failed to meet rib fat specifications which equates to 14.3% of those contained in dataset B. In agreement with Figures 6, 13 and 21, most carcasses that missed rib fat specifications were toward the fatter end of the rib fat grid (13.4%).

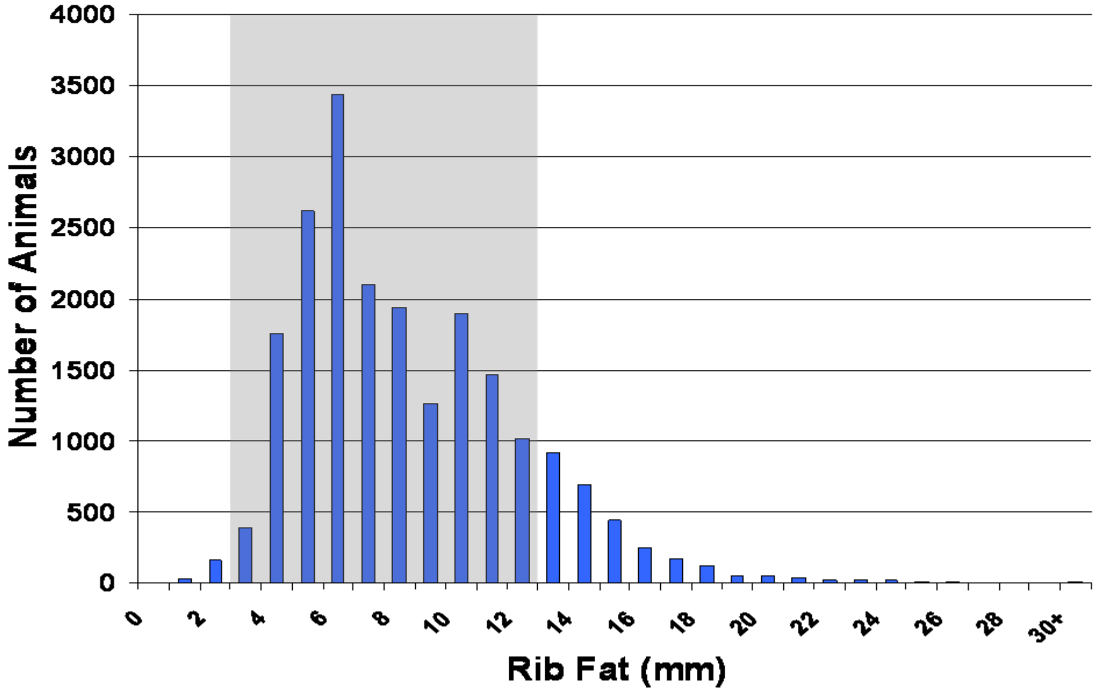

Figure 28. The distribution of rib fat (mm) of heifers from dataset B. The rib fat range where no price discounts apply is shaded in grey.

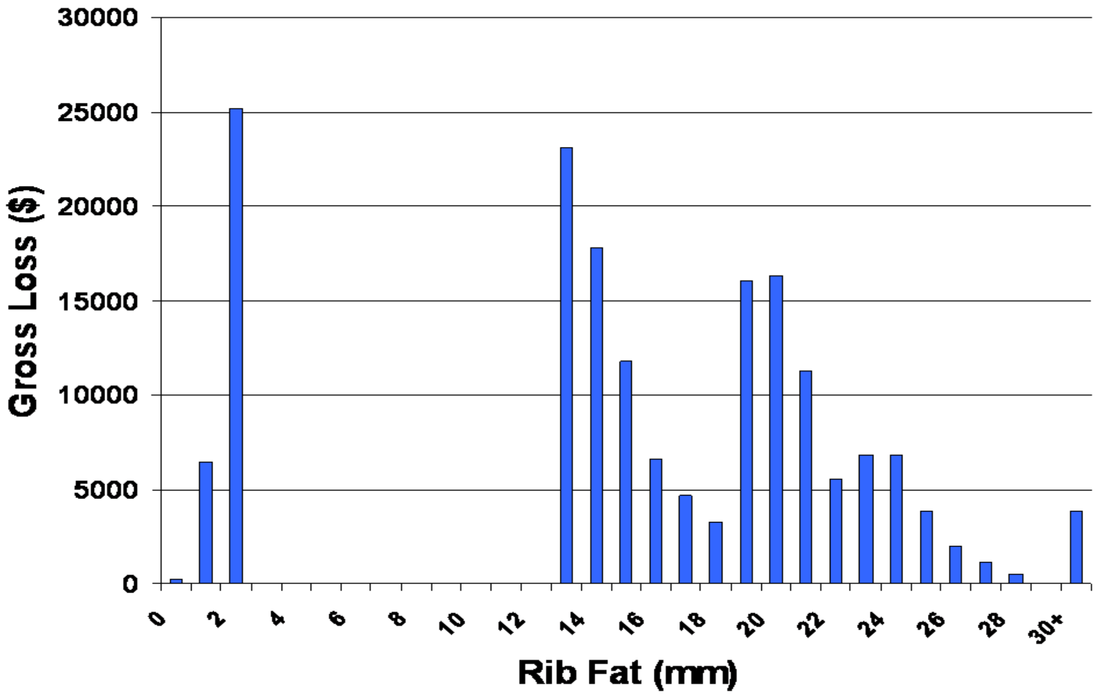

Figure 29. Gross loss ($) for heifer carcasses in dataset B that failed to meet rib fat market specifications.

The financial loss associated with 14.3% of heifer carcases in dataset B failing to meet rib fat specifications is demonstrated in Figure 29. These losses equate to a total gross loss of $173,132 with 81.6% ($141,345) being accounted for by over-fat carcasses which supports the result seen in Figures 7, 14 and 22. When averaged over those carcasses that did not meet specifications the losses were $57.98 per heifer carcass. In comparison, when averaged across all 20,848 heifer carcasses contained in dataset B these losses result in an $8.30 loss per carcass. In contrast to Figure 14 the losses on a per carcass contained in the dataset basis these losses are lower but not substantially different to those in Figures 7 and 22.

- Heifer Combined Results

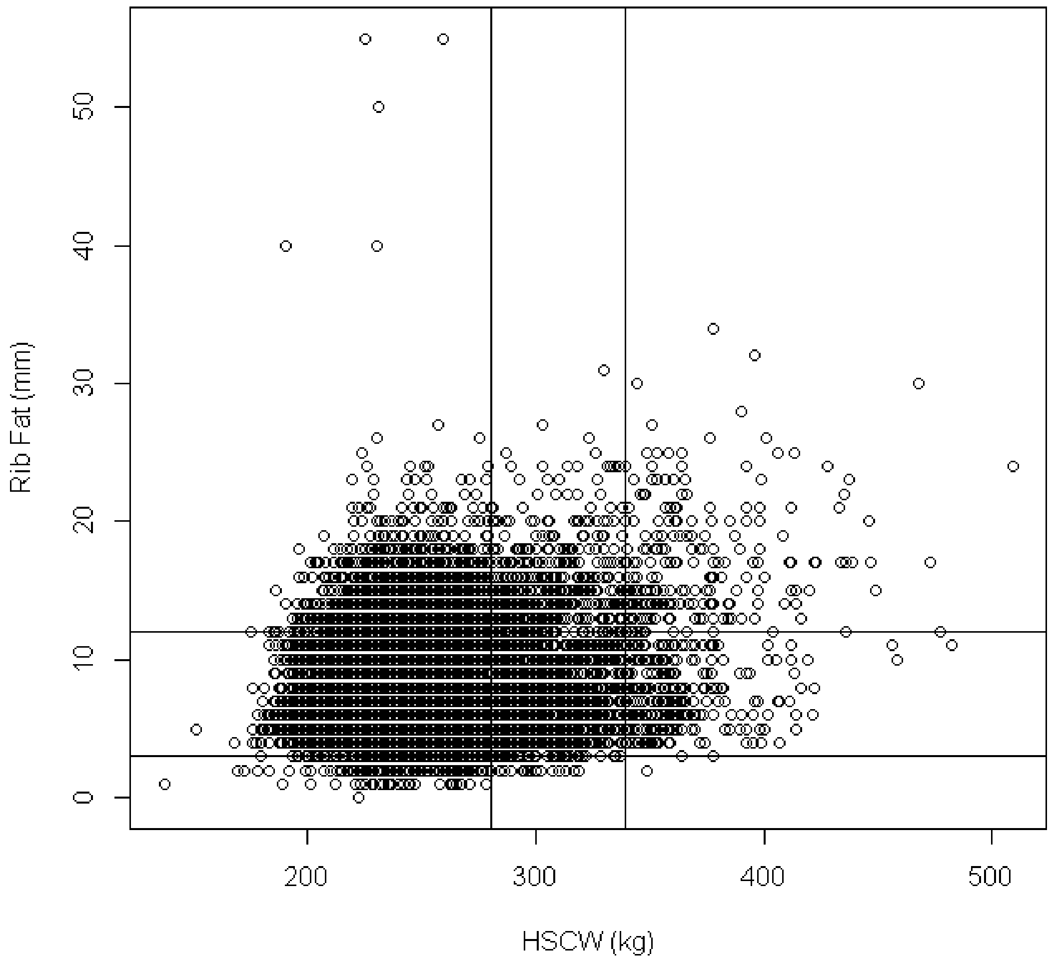

Figure 30. Relationship between HSCW (kg) and rib fat (mm) of heifers in dataset B with vertical lines representing ideal HSCW specifications of 280 kg and 339 kg and horizontal lines representing ideal rib fat specifications of 3 mm and 12 mm.

Figure 30 illustrates that some heifer carcasses in dataset B fail to comply with HSCW specifications while others fail to comply with rib fat specifications and others fail to comply with both HSCW and rib fat specifications. A total of 90.7% of the heifer carcasses in dataset B fail to comply with HSCW or rib fat specifications or both. The resulting total gross loss is $1,718,447. When averaged over those carcasses that did not meet specifications the losses were $90.86 per heifer carcass which is comparable to that found in Figure 15. In comparison, when averaged across all 20,848 heifer carcasses contained in dataset B these losses were $82.43 per carcass which. This result is substantially higher than the results seen in figures 8 and 15 and is a reflection of the large percentage of heifer carcasses that failed to meet HSCW specifications.

A summary of the percentage of carcasses out-of-specification (%), total gross loss ($), loss per heifer carcass failing to meet specifications ($/carcass) and loss per carcass for all heifers contained in dataset B ($/carcass) is reported in Table 5. The results in Table 5 support the results described above for Tables 2, 3 and 4 in that losses due to failing to comply with HSCW or rib fat specifications are not additive and that some double counting of animals missing specifications does occurs when HSCW and rib fat are analysed independently. Once again comparison of the losses per heifer in dataset B demonstrates little difference between losses when HSCW and rib fat are analysed independently or in conjunction ($75.56 + $8.30 = $83.86 vs. $82.43). A similar result is also seen when comparing the total gross loss ($1,575,266 + $173,132 = $1,748,398 vs. $1,718,447). Both approaches result in a 1.7% upwards bias when analysing HSCW and rib fat independently. In contrast, if the losses are reported on a per animal failing specifications basis ($85.64 + $57.98 = $143.63 vs. $90.86) large quantities of bias are introduced (58.0%).

Table 5. The proportion of heifer carcasses that failed to meet specifications, total gross loss ($), loss per heifer carcass failing to meet specifications ($/carcass) and loss per heifer carcass in dataset B ($/carcass) when HSCW and rib are analysed independently or in conjunction.

Item	HSCW[1]	Rib fat[1]	Both[1]
Out-of-specification (%)	88.2	14.3	90.7
Total Gross loss ($)	$1,575,266	$173,132	$1,718,447
Loss / Steer failing specifications ($/carcass)	$85.64	$57.98	$90.86
Loss / Steer contained in dataset A ($/carcass)	$75.56	$8.30	$82.43

[1]number of heifer carcasses = 20,848

The compliance rates explored above in datasets A and B provide the first quantitative assessment of grass-fed compliance rates in the Australian beef industry. The non-compliance rates found in dataset A were slightly lower (15-17%) for HSCW compared to the feedlot study (28%) conducted by Slack-Smith et al. (2009). In contrast the non-compliance rates for fatness were similar (13-19% dataset A and 16% found by Slack-Smith et al. (2009)). In agreement with Slack-Smith et al. (2009) most carcasses in dataset A were non-compliant for being over-weight or over-fat. In contrast, the non-compliance rates for HSCW in dataset B are substantially higher than those found by Slack-Smith et al. (2009) (44-88% vs. 28%) while the fatness non-compliance rates were also similar (14-18% dataset B vs. 16%).The high non-compliance rates for HSCW in dataset B suggest that the carcass grid provided by the abattoir may not be relevant for the steers and heifer contained in dataset B even following data editing on the steer portion of the dataset.

3.3.2 Economic costs to processor

3.3.2.1 Dataset A

- HSCW

The economic costs of carcasses in dataset A failing to meet a target HSCW of 280 kg (m) while carcass fatness (7.5 mm) is ideal are illustrated in Figure 31. The deviation of the point of intolerance from the target value was determined from Figures 2 and 9 to be 60 kg (Δ_o) above and below the target value. The monetary loss (A_o) of a 220 kg carcass was calculated to be $100.00 which produced a quality loss coefficient (k) of 0.02778. The monetary loss (A_o) of a 340 kg carcass was calculated to be $165.00 which produced a quality loss coefficient (k) of 0.04583. Relatively small economic losses are incurred by carcasses that have small deviations from the target value, 280 kg. A 270 kg carcass was predicted to lose $2.78 while a 290kg carcass was predicted to lose $4.58. As expected due to the structure of the TQL function carcasses with large deviations from the target value had extremely large losses. A 130 kg carcass was predicted to lose $625.00 and a 510 kg carcass was predicted to lose $2,424.58.

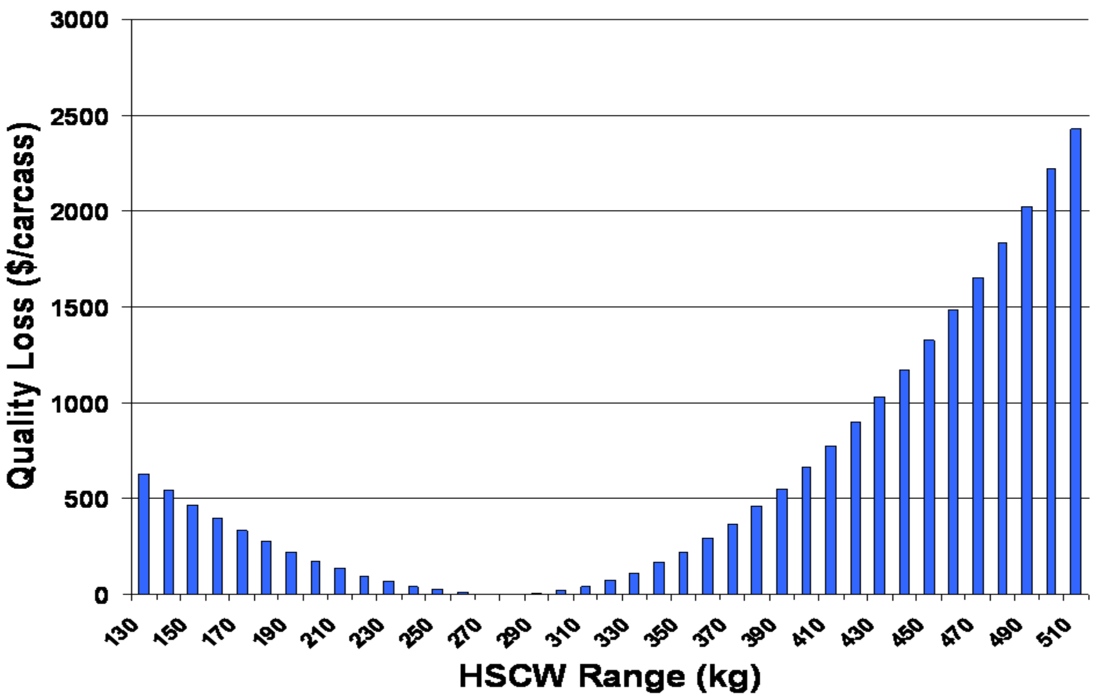

Figure 31. The economic cost of carcasses that fail to comply with HSCW specifications termed quality loss ($/carcass) predicted using the Taguchi Quadratic Loss Function in dataset A.

The estimates of economic losses from Figure 31 were ground-truthed by following the steps in the process used to estimate the monetary loss values. If the worst case scenario was assumed where all primals from a carcass are only able to be used for ground beef and mince is valued at $4.50/kg a 130 kg carcass with a 60% retail meat yield would be worth $351.00. If 70% of the primals from this same carcass could be sold for an average price of $11/kg with the remainder sold as ground beef the carcass would be worth $705.90. This equates to a loss of $354.90 which is $270.10 smaller than the economic loss predicted by the TQL function for a 130 kg carcass. In comparison, a 510 kg carcass with a retail meat yield of 65% that produced solely ground beef would be worth $1,491.75 while the same carcass that produced saleable primals would be worth $3,000.08. This equates to a loss of $1,508.33 which is $916.26 smaller than the economic loss predicted by the TQL function.

- Rib Fat

The economic costs of carcasses failing to meet a target rib fat of 7.5 mm (m) while HSCW (280 kg) is ideal are illustrated in Figure 32. The deviation of the point of intolerance from the target value was determined from Figures 5 and 12 to be 5.5 mm (Δ_o) above and below the target value. The monetary loss (A_o) of a carcass with 2 mm of rib fat was calculated to be $275.00 which produced a quality loss coefficient (k) of 9.09091. The monetary loss (A_o) of a carcass with 13 mm of rib fat was calculated to be $125.00 which produced a quality loss coefficient (k) of 4.13223. Relatively small economic losses are incurred by carcasses that have small deviations from the target value, 7.5 mm. A 280 kg carcass with 6 mm of rib fat was predicted to lose $20.45 while a 280 kg carcass with 9 mm of rib fat was predicted to lose $9.30. As expected due to the structure of the TQL function carcasses with large deviations from the target value had extremely large losses. A 280 kg carcass with 0 mm of rib fat was predicted to lose $511.36 and a 280 kg carcass with 30 mm of rib fat was predicted to lose $2,091.94.

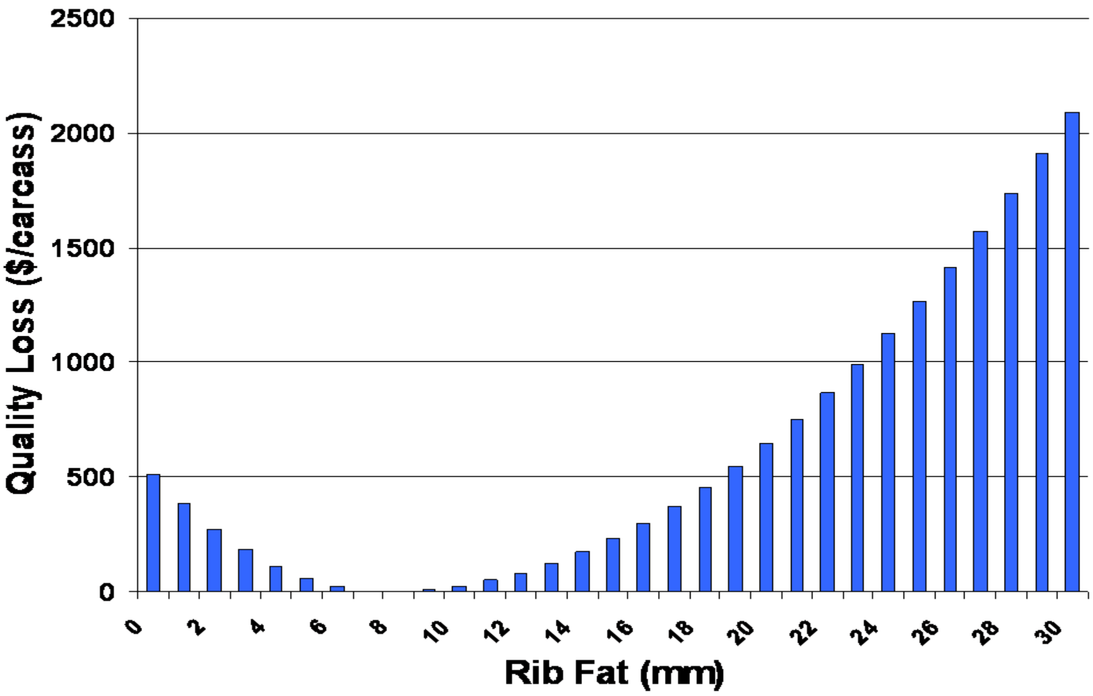

Figure 32. The economic cost of carcasses that fail to comply with rib fat specifications termed quality loss ($/carcass) predicted using the Taguchi Quadratic Loss Function in dataset A.

The estimates of economic losses from Figure 32 were also ground-truthed by following the steps in the process used to estimate the monetary loss values. If the worst case scenario is assumed again where all the primals from a carcass are used for ground beef and mince is valued at $4.50/kg a 280 kg carcass with 0 mm of rib fat and a 70% retail meat yield would be worth $882.00. If 70% of the primals from this same carcass could be sold for an average price of $11/kg with the remainder sold as ground beef the carcass would be worth $1,499.40. This equates to a loss of $617.40

which is $106.04 larger than the economic loss predicted by the TQL function for a 280 kg carcass with 0 mm rib fat. In comparison, a 280 kg carcass with 30 mm of rib fat and a retail meat yield of 48% that produced solely ground beef would be worth $598.50 while the same carcass that produced saleable primals would be worth $1,773.80. This equates to a loss of $1,175.30 which is $916.64 smaller than the economic loss predicted by the TQL function.

3.3.2.2 Dataset B

- HSCW

The economic costs of carcasses in dataset B failing to meet a target HSCW of 310 kg (m) while carcass fatness (7.5 mm) is ideal are illustrated in Figure 33. The deviation of the point of intolerance from the target value was determined from Figures 16 and 24 to be 30 kg (Δ_o) above and below the target value. The monetary loss (A_o) of a 280 kg carcass was calculated to be $135.00 which produced a quality loss coefficient (k) of 0.15. The monetary loss (A_o) of a 340 kg carcass was calculated to be $165.00 which produced a quality loss coefficient (k) of 0.18333. Similar to Figure 31 relatively small economic losses are incurred by carcasses that have small deviations from the target value, 310 kg. A 300 kg carcass was predicted to lose $15.00 while a 320kg carcass was predicted to lose $18.33. As expected due to the structure of the TQL function carcasses with large deviations from the target value had extremely large losses however these are much larger than those presented in Figure 31. A 130 kg carcass was predicted to lose $4,860.00 and a 510 kg carcass was predicted to lose $7,333.33.

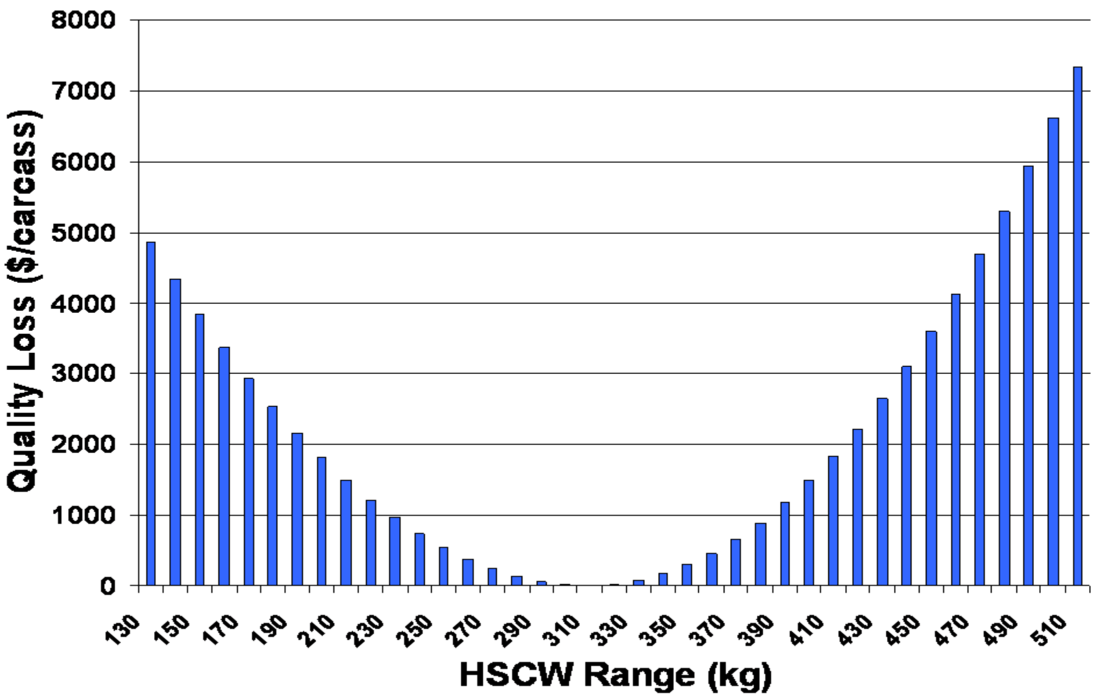

Figure 33. The economic cost of carcasses that fail to comply with HSCW specifications termed quality loss ($/carcass) predicted using the Taguchi Quadratic Loss Function in dataset B.

The estimates of economic losses from Figure 33 were again ground-truthed by following the steps in the process used to estimate the monetary loss values. As described above in conjunction with Figure 31, a 130 kg carcass only producing ground beef would be worth \$351.00 or \$705.90 if 70% of the primals were sold for an average price of \$11/kg with the remainder sold as ground beef which equates to a loss of \$354.90. However, the differences in the HSCW grid between datasets A and B mean this loss is \$4,505.10 smaller than the economic loss predicted by the TQL function. In comparison, following the logic above a 510 kg carcass that produced only ground beef would be worth \$1,491.75 while the same carcass that produced saleable primals would be worth \$3,000.08 equating to a loss of \$1,508.33. The HSCW grid differences between the two datasets mean this loss is \$5,825.01 smaller than the economic loss predicted by the TQL function. In both cases the predicted losses are far in excess of those predicted in dataset A and are greater than the carcass values estimated during the ground truthing.

- Rib Fat

The economic costs of carcasses in dataset B failing to meet a target rib fat of 7.5 mm (m) while HSCW (310 kg) is ideal are illustrated in Figure 34. The deviation of the point of intolerance from the target value was determined from Figures 20 and 27 to be 5.5 mm (Δ_o) above and below the target value. The monetary loss (A_o) of a carcass with 2 mm of rib fat was calculated to be \$300.00 which produced a quality loss coefficient (k) equal to 9.91736. The monetary loss (A_o) of a carcass with 13 mm of rib fat was calculated to be \$140.00 which produced a quality loss coefficient (k) equal to 4.6281. Once again relatively small economic losses are incurred by carcasses that have small deviations from the target value, 7.5 mm. A 310 kg carcass with 6 mm of rib fat was predicted to lose \$22.31 while a 310kg carcass with 9 mm of rib fat was predicted to lose \$10.41. Extreme large losses were again predicted for carcasses with large deviations from the target value. A 310 kg carcass with 0 mm of rib fat was predicted to lose \$557.85 and a 310 kg carcass with 30 mm of rib fat was predicted to lose \$2,342.98.

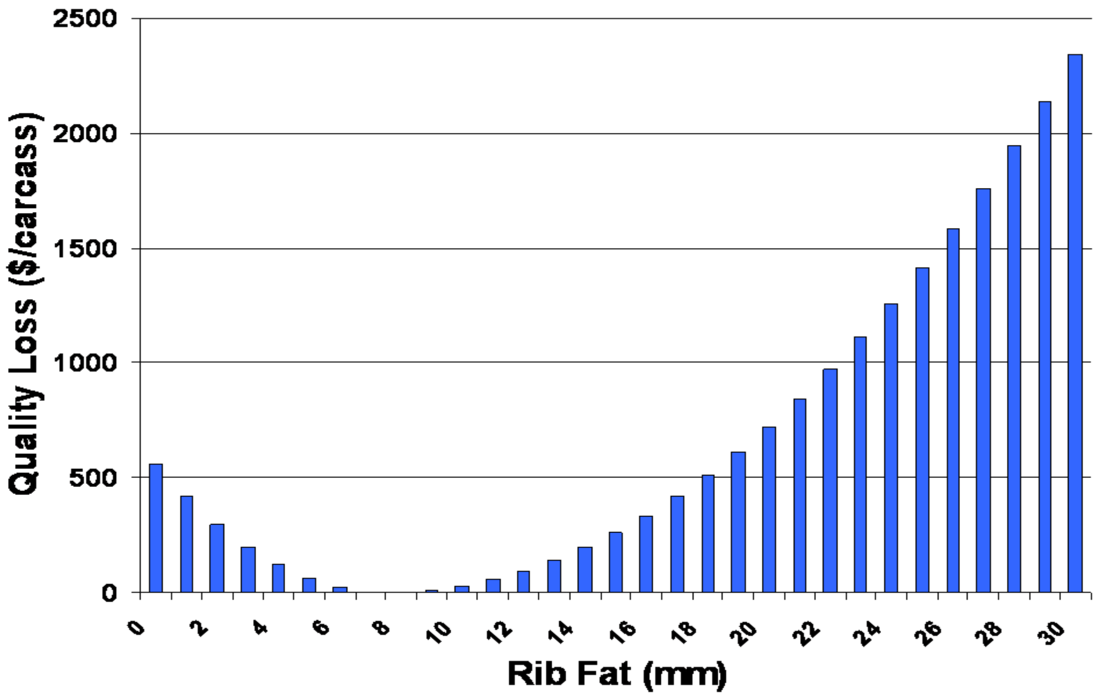

Figure 34. The economic cost of carcasses that fail to comply with rib fat specifications termed quality loss (\$/carcass) predicted using the Taguchi Quadratic Loss Function dataset B.

The estimates of economic losses from Figure 34 were again ground-truthed by following the steps in the process used to estimate the monetary loss values. In the worst case scenario where all the primals from a carcass are used for ground beef and mince is valued at $4.50/kg a 310 kg carcass with 0 mm of rib fat and a 70% retail meat yield would be worth $976.50. If 70% of the primals from this same carcass could be sold for an average price of $11/kg with the remainder sold as ground beef the carcass would be worth $1,660.05. This equates to a loss of $683.55 which is $125.70 larger than the economic loss predicted by the TQL function for a 310 kg carcass with 0 mm rib fat. In comparison, a 310 kg carcass with 30 mm of rib fat and a retail meat yield of 48% that produced solely ground beef would be worth $662.63 while the same carcass that produced saleable primals would be worth $1,963.85. This equates to a loss of $1,301.23 which is $1,041.75 smaller than the economic loss predicted by the TQL function.

The predictions of economic losses made by the TQL function for carcasses that fail to achieve target values raise some concern. Although losses within the range of the points of intolerance seem within the confines of reality beyond the points of intolerance the losses are predicted to increase quickly following the quadratic nature of the TQL function to values that are considered unrealistic. If abattoirs were actually forced to absorb losses of this magnitude they would be highly unviable given some of the losses predicted are greater than the value of the carcass when it meets specifications and can be sold for the highest value. The structure of the TQL function appears to be the limiting factor when attempting to implement it for evaluating losses incurred by processors trying to market carcasses that fail to meet specifications. The TQL function assumes a product has no effective use or value beyond the point of intolerance which is why a consumer makes a corrective action. In contrast, a carcass grid is structured to reflect the reality that a carcass still has value, although diminished, when it does not comply with carcass specifications. In most circumstances (under- over-weight and under-fat carcasses) there is little corrective action a consumer (processor) can take to move the product (primals) to the ideal value rather they find an alternative destination which can utilise the product characteristics. The exception is when a carcass is over-fat and excessive fat can be trimmed to some degree (obviously no IMF fat can be removed) to bring the fatness back to a desirable level. However, even in this circumstance the TQL function made large over predicts of carcass losses.

The economic losses presented above are driven by the difference between the point of intolerance (t), the target value (m) and the monetary loss (A_o) incurred by action taken at the point of intolerance. The target value and the point of intolerance are quite readily defined by the range of trait values in the carcass grid where no price discounts are imposed on the producer by the abattoir. Even though the difference between the target value and the point of intolerance (Δ_o) has a large impact on the quality loss coefficient (k) it is characterised by the indicative grids used in this study and thus are not open to alternative methods for determination. The monetary loss incurred at the point of intolerance has equally large impacts on the quality loss coefficient. Alternative methods could be employed for estimating the monetary losses which contrast to the method used in this study. Consequently alternative methods would result in different economic losses being predicted which could be larger or smaller than those predicted here.

4. Concluding remarks on non-compliance study

The datasets (A and B) and indicative grids provided by commercial abattoirs have provided a snapshot of carcass compliance rates in grass-fed markets. The non-compliance of carcasses from steers in dataset A were 17.4% and 13.0% for HSCW and rib fat, respectively while the non-compliance rates in heifer carcasses were 15.6% and 19.1% for HSCW and rib fat, respectively. The corresponding non-compliance rates of steer carcasses in dataset B were 44.8% and 18.5% for HSCW and rib fat, respectively while those for heifers were 88.2% and 14.3%, respectively. It is evident that the non-compliance rates for HSCW are substantially higher in dataset B while the non-compliance rates for rib fat are comparable between the two datasets. Slack-Smith et al. (2009) found HSCW non-compliance rates in a short-fed (100 days on feed) feedlot dataset to be 28% which is slightly higher than those found in dataset A but substantially lower than those found dataset B. The rib fat non-compliance rates in both datasets A and B were similar to the 16% P8 fat non-compliance found by Slack-Smith et al. (2009). These results suggest non-compliance rates for fatness are generally in the range of 10 to 20%. However, the HSCW results suggest that the much more demanding structure of the indicative grid supplied for dataset B is not relevant for this dataset and therefore over inflates the non-compliance rates. It is suggested that the non-compliance rates for dataset A give a truer indication of general grass-fed non-compliance within the Australian beef industry.

The TQL function was applied to both indicative grids supplied for datasets A and B in an attempt to try and quantify the economic losses incurred by the processing sector when carcasses do not comply with carcass targets. The TQL function has been successfully applied in the engineering sector (Taguchi et al. 1999) to quantify such losses. Application of the TQL function to datasets A and B resulted in small economic losses occurring when carcass traits were within the range of the grid where no price discounts are applied. These losses were considered realistic when compared to a ground-truthing exercise. However, as the carcass traits moved further away from the target value the predicted losses increased rapidly. In some cases these values were higher than the maximum value of the carcass determined in the ground-truthing exercise. The point of intolerance used by the TQL function represents the point when a product characteristic reaches a value when it is no longer of any use to the consumer and thus requires correction to become useful. Although corrective action may be required to on sell non-compliant carcasses, in the form of sourcing new markets for under-weight carcasses or trimming excessively fat carcasses for example, non-compliant carcasses are not of zero value to the processing sector. This is reflected in the structure of the carcass pricing grids supplied for each dataset where carcasses beyond the ideal trait range receive penalties which are not equal to the price received for a carcass with ideal traits rather they are smaller. These results suggest the TQL function is not the appropriate method for ascertaining the losses incurred by the processing sector of the Australian beef industry when carcasses do not comply with carcass specifications. It is suggested that alternative methods are explored.

5. Sensitivity analysis of BeefSpecs inputs

5.1 Introduction

The accuracy of P8 fat predicted by BeefSpecs at the end of a feeding period has important implications for how BeefSpecs can be implemented in the beef industry and the quality of decisions producers can make with its assistance. Some of the inputs into BeefSpecs require a degree of technical training to estimate, e.g., estimating initial P8 fat (mm) by manual palpation. This study has examined the impacts that the accuracy of inputs to BeefSpecs has on prediction accuracy. The potential value of increasing the accuracy of estimating inputs will be considered.

5.2 Methods

The sensitivity analysis in this study used Equation 3 taken from Saltelli et al. (2000, page 5) to investigate the sensitivity of the BeefSpecs outputs relative to BeefSpecs inputs. Equation 2 is defined mathematically as –

$$S_{i,j} = \partial Y_i / \partial X_j \qquad \text{Equation 3}$$

where X_j is the model input variable j, Y_i is the model output variable i, and $S_{i,j}$ is the sensitivity (of the output Y_i relative to the input X_j).

The latest version of BeefSpecs was used to provide the output/input variables for a factorial sensitivity analysis (Saltelli and Annoni, 2010). A matrix with 57,600 rows of inputs and outputs was created by incrementally changing the inputs one variable at a time. The input variables included; sex, feed type, hormonal growth promotant, breed type, days on feed (DOF), frame score, initial P8 fat (mm), initial weight (kg) and growth rate (kg/day) (Table 6). The P8 fat (mm) predicted by BeefSpecs and the calculations using equation 3 were also incorporated into this matrix. An analysis of variance (ANOVA) on the 9-way factorial matrix was conducted using Genstat (2011) to investigate the dominant effects and interactions.

Table 6. Input variables for the factorial sensitivity analysis of BeefSpecs.

Input Variable	Levels -
Sex	Steer, Heifer
Feed Type	Grass, Grain
Hormonal growth promotant	None, Oestrogen, Androgen
Breed	British, European, Bos indicus, 3-way cross
Days on feed	60, 120, 180
Frame Score	2, 4, 6, 8
Initial P8 fat (mm)	2, 4, 6, 8, 10
Initial Weight (kg)	200, 250, 300, 350, 400
Growth rate (kg/d)	0.5, 1.0, 1.5, 2.0

5.3 Results and discussion

Table 7 lists a summarisation of the ANOVA table for final P8 fat depth, including R^2 (as in Saltelli et al. 2000), which measures the cumulative amounts of total variation accounted for at each step. When analysing the simulation output from the approach outlined by Saltelli et al. (2000) it is the relative sizes of the F-values in Table 7 that need to be considered rather than the formal statistical significance levels (Mayer et al. 1994).

Table 7. Summary of the ANOVA table for final P8 fat depth.

ANOVA terms	Avg. F-values[1]	Multiplier (vs. next level)	Cum. R^2 (%)
Main effects	248,899,111	48	84.822
2-way intns.	5,157,629	111	99.342
3-way intns.	46,433	85	99.942
4-way intns.	544	5	99.977
5-way intns.	118	8	99.998
6-way intns.	14	8	99.999
7-way intns.	2		100.000

[1.] When analysing simulation output, it is the relative sizes of the F-values that need to be considered, rather than the formal statistical significance levels (Mayer et al. 1994).

Table 7 shows that the majority of the information will be contained at the 3 or 4-way interaction level. The key model input parameters contributed to a dominant 4-way interaction between 'sex x frame score x initial weight x initial P8 fat', with $F_{(48, 9504)}$ = 6,255. Tables 8 and 9 highlight the sensitivity of P8 fat predictions to frame score and initial P8 fat.

Table 8. Sensitivity (mm/unit) of final P8 fat against frame score.

Frame	**Initial**	**60 DOF**		**120 DOF**		**180 DOF**	
score	**weight (kg)**	Heifer	Steer	Heifer	Steer	Heifer	Steer
Low	200	-0.45	-0.29	-0.77	-0.60	-1.23	-0.71
(2 to 4)	250	-0.56	-0.32	-1.00	-0.67	-1.61	-0.87
	300	-0.65	-0.38	-1.32	-0.73	-2.01	-1.10
	350	-0.83	-0.47	-1.63	-0.87	-2.29	-1.38
	400	-0.83	-0.56	-1.49	-1.09	-2.11	-1.66
High	200	-0.26	-0.17	-0.56	-0.35	-0.67	-0.56
(6 to 8)	250	-0.30	-0.18	-0.61	-0.39	-0.83	-0.59
	300	-0.36	-0.19	-0.68	-0.45	-1.08	-0.61
	350	-0.45	-0.22	-0.86	-0.51	-1.34	-0.68
	400	-0.53	-0.27	-1.07	-0.58	-1.60	-0.82

Table 8 shows that final P8 is sensitive to the accuracy of estimating frame score. For each unit of error in estimating frame score, the error in final P8 predicted by BeefSpecs will be up to 2.3 mm (absolute) for heifers and up to 1.7 mm (absolute) for steers; i.e. if frame score was estimated with an error of 2 frame scores there would be a likely error of up to 4.6mm and 3.5mm for heifers and steers, respectively.

Table 9. Sensitivity (mm/mm) of final P8 fat against initial P8

Initial P8 fat	Frame Score	Sex	Initial weight (kg) 200	250	300	350	400
Low (2 to 4)	2	Heifer	1.45	1.28	1.15	0.88	0.66
	2	Steer	1.52	1.37	1.31	1.18	0.81
	4	Heifer	1.50	1.35	1.23	0.91	0.47
	4	Steer	1.52	1.39	1.34	1.22	0.84
	6	Heifer	1.52	1.39	1.28	0.95	0.47
	6	Steer	1.51	1.38	1.34	1.23	0.87
	8	Heifer	1.53	1.40	1.31	0.99	0.49
	8	Steer	1.48	1.36	1.33	1.23	0.87
High (8 to 10)	2	Heifer	1.17	1.00	0.88	0.78	0.81
	2	Steer	1.27	1.13	1.03	0.96	0.87
	4	Heifer	1.23	1.06	0.98	0.87	0.79
	4	Steer	1.29	1.16	1.07	1.00	0.95
	6	Heifer	1.27	1.13	1.03	0.95	0.87
	6	Steer	1.31	1.17	1.08	1.03	0.98
	8	Heifer	1.30	1.16	1.07	1.00	0.94
	8	Steer	1.32	1.18	1.09	1.04	1.00

Table 9 shows that final P8 fat is sensitive to the accuracy of estimating initial P8 fat. For each unit of error in estimating initial P8 fat the error in predictions of final P8 by BeefSpecs will be up to 1.5 mm for heifers and steers; i.e. if initial P8 fat (mm) was estimated with an error of 2 mm there would be a likely error in final P8 fat predictions of up to 3.0 mm for both heifers and steers.

Table 10 shows that the accuracy of estimating initial weight is not anywhere near as critical as lack of accuracy in estimating either frame score or P8 fat. . A 10kg error in estimated initial weight (i.e., at induction) will result in a maximum error of 0.5 mm in the predicted final P8 fat (mm).

Table 10. Sensitivity (mm/kg) of final P8 fat (mm) against initial weight (kg)

Initial weight (kg)	Frame score	60 DOF		120 DOF		180 DOF	
		Heifer	Steer	Heifer	Steer	Heifer	Steer
Low (200 to 250)	2	-0.009	-0.015	0.003	-0.009	0.028	-0.001
	4	-0.013	-0.016	-0.006	-0.011	0.013	-0.008
	6	-0.016	-0.017	-0.009	-0.014	0.001	-0.009
	8	-0.017	-0.017	-0.011	-0.016	-0.005	-0.010
High (350 to 400)	2	0.021	0.012	0.035	0.025	0.048	0.038
	4	0.021	0.009	0.041	0.016	0.055	0.027
	6	0.015	0.006	0.031	0.012	0.047	0.018
	8	0.012	0.004	0.022	0.010	0.036	0.013

Analyses of carcass weight which is also an output from BeefSpecs provided little information. Live weights at the end of a feeding period are determined directly (i.e., without any random variation) from initial live weight, growth rate and days on feed, and then carcass weights are calculated directly by applying the assumed dressing percentages to these final live weights. Hence, carcass weights are only dependent on these factors, as well as being insensitive to the key model inputs of frame score and initial P8 fat (supported by the results from the ANOVA).

6. Concluding remarks on sensitivity analysis

The results from the sensitivity analysis suggest that the accuracy of predictions made by BeefSpecs are very sensitive to the accuracy of estimates of P8 fat and frame score. Numerous avenues are available for increasing the accuracy of measuring inputs to BeefSpecs. The development of technology in the form of image analysis offers the opportunity to assess animal characteristics such as frame score and initial P8 fat that are currently assessed using a subjective score such as fat score. In the intervening time between the research and development of such technology and its release to industry there is the opportunity for cattle producers to improve their skills in live animal assessment. Developing these technologies and improving the skill set of beef producers will facilitate improved accuracy in BeefSpecs inputs which, in turn, will improve the decision-making of producers seeking to improve compliance with market specifications.

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