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Report Title: Re-analysis of beef carcase pricing data with less variation in yield in carcases analysed

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Abstract

This analysis mimics that completed by Pitchford *et al.* (2020) however with ‘extreme’ carcasses removed to endeavour to better mimic an average processing day, with the aim that the conclusion should change. Again, six methods were used to calculate carcass price ($/kg). Changes to dataset did not result in corresponding change in results, therefore the previous conclusion remains unchanged; that actual measurement of yield is crucial to determining carcass values and providing market signals to beef producers.

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Executive Summary

Hereford cross steer carcasses (153) were boned out to record saleable meat and yield. Six methods were used to calculate carcass price ($/kg). All were adjusted to the same average carcass value to allow comparisons assuming that overall payment does not change, but distinguishing between increased quality (greater premiums and discounts). The six prices were based on a commercial grid, grid plus eating quality premium, yield of saleable meat only (constant price for all saleable meat), yield with eating quality premium, then the yield prices with optimum (quadratic) weight and fatness penalties based on grid optimums. This analysis repeated methods that have previously been published on the same data set. However, ‘extreme’ breed combinations (Jersey and Belgian Blue sired) were removed, leaving a data set of 108 carcasses, from Wagyu, Angus, Hereford, South Devon and Limousin sired steers by Hereford dams. The aim was to address concerns that the data set was not representative of commercial data. Despite the removal of these carcasses, the results of the previous analysis remain unchanged. That is, measurement of yield accounts for substantial variation in prices calculated from yield and eating quality, and is therefore a large driver of value of the carcass. The next step in the research is to test the soundness of the models against multiple other data sets, as well as define how much variation should be seen within a dataset to ensure it is representative of industry variation.

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1 Introduction

Beef processing plants are concerned with total production, the number and weight of carcasses process, with weight and fat primarily determining carcass value. When a carcass is able to combine saleable yield and eating quality at optimum levels, a processor may be able to extract greater value. Saleable Meat Yield has been defined as a combination of Lean Meat Yield and customer cutting specifications which may include different levels of bone and trim. Eating quality is determined by Meat Standards Australia, and defined at a carcass level. Research previously completed to develop a continuous pricing structure determined the price, and consequently the value, are largely driven by yield. However, a large amount of anecdotal evidence has come to light, which argues against this conclusion, stating that eating quality drives the price and value. This raises the question whether the models and prices are robust, and reflective of what abattoirs see on an average day. To ensure this question can be answered, the previous analysis was re-run with some modifications to the data set; that is the removal of very small or very large carcasses (classed as ‘extreme’ carcasses) which may be driving the yield influence. Thus, the aim of this paper is to test the hypothesis that the conclusions made in the previous analysis will change when the extreme breed crosses are removed from the data set and the analysis re-run.

2 Methods

Hereford cross steer carcasses (153) were graded, boned out and had intramuscular fat measured. All were from the Southern Cross Breeding Project born in 1995 (Pitchford *et al*. 2002). The project crossed Hereford cows to seven diverse sire breeds: Jersey, Wagyu, Angus, Hereford, South Devon, Limousin and Belgian Blue, producing a large range of carcass types for yield and intramuscular fat. Calves were born on two properties in Autumn, brought together at weaning, lot fed for 150 days from 620 days of age and slaughtered in seven randomly selected groups during May 1997. Carcass weight (HSCW, kg) and Rump P8 fat depth (P8, mm) were recorded commercially. Loin eye muscle area (EMA, cm^2) was

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recorded at the 10/11th rib site and samples of this muscle were taken for intramuscular fat (IMF, %) measurement. All carcasses were boned out to standard 6mm trim, recording weights of all cuts, bone, fat and trim. Trim weights were adjusted to 85% chemical lean before calculating Saleable Meat Yield (SMY, %) as the sum of all saleable cuts and trim. For this analysis the 'extreme' carcasses being the Jersey and Belgian Blue crosses were removed from the original dataset before the analysis was replicated. This removal resulted in a dataset of 108 carcasses from Wagyu, Angus, Hereford, South Devon and Limousin x Hereford crosses. Even as a smaller dataset, the carcasses still showed considerable variation (Table 1) given they were all from the same management group with negligible variation in age, for examples HSCW ranged 334.9-415.6 kg, P8 from 6-32mm, EMA 41-105cm^2 and SMY 62.6-73.1%.

Table 1 Summary Statistics of carcass data

Trait	Mean	Minimum	Maximum	SD
Carcass weight (HSCW, kg)	334.9	234.8	415.6	35.5
Rump P8 fat depth (P8, mm)	16.4	6.0	32.0	5.76
Intramuscular fat (IMF, %)	4.34	1.0	10.9	1.91
MSA marbling (MB, calc score)	361.3	290	490	38.1
Loin eye muscle area (EMA, cm^2)	72.1	41.0	105.0	11.0
Saleable meat yield (SMY, %)	67.2	62.6	73.1	2.40
MSA Index (Units)	65.2	63.4	68.0	0.82

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2.1 MSA eating quality scores

Carcasses were processed before MSA was commercially available and so no MSA grading data was available. To allow MSA eating quality prediction, input data had to be estimated to run the MSA model. Given all carcasses were young and the same age (AUSMEAT cypher YG, approximately 2 years, average 770 days) ossification score was assumed to be 170. Rib fat depth was assumed to be 80% of P8. Marble score (MB) was calculated as 20 × IMF + 277 (unpublished data) and rounded down to the nearest 10 to match MSA visual marble scores. IMF and MB were not exactly the same trait (r=0.996) as MB was rounded to the nearest 10 for input into the MSA model. All cattle were zero *Bos indicus* content, grain fed and not treated with hormone growth promotant. Carcasses were Achilles hung and it was assumed their pH was 5.5 to remove any effect of stress or dark cutting. Finally, it was assumed that all cuts were aged for 7 days. The MSA model was used to predict eating quality scores for all cut by cooking method options. The highest eating quality score (best cooking method) for each cut was used for all eating quality price models.

2.2 Calculating carcass value and price

Carcass value ($/carcass) and price ($/kg HSCW) were determined using six different pricing models, based on

- a grid,
    a. Grid Only or; (GO)
    b. Grid plus Eating Quality (GEQ)
- a continuous pricing model based on SMY
    a. without optimum HSCW or P8
        i. assuming a zero eating quality premium; (YO)
        ii. assuming a high eating quality premium, or; (YEQ)
    b. with optimum HSCW and P8 (based on grid optimums)

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i. assuming a zero eating quality premium; (YOO)

ii. assuming a high eating quality premium. (YEQO)

2.3 Price grid development

Grid Only No Eating Quality Premium GO

The price grid used for this project (Table 2) was developed from three publicly available price grids for different weeks of 2017 from three separate processors: 1) Thomas Foods International, Angus Pure Week 11; 2) Teys Australia Naracoorte, April, and; 3) Bindaree Beef Australia, July. This procedure was considered reasonable as the differences were mostly a function of the base price which fluctuates seasonally with cell discounts being similar, varying little between the grids. Combining the three grids resulted in Table 2, which matched broader industry guidelines, and could cope with the variation seen between carcasses.

Table 2: Reference price grid. Deductions ($/kg) exclude eating quality premiums.

		HSCW (kg)					
		<200	200-240	240-320	320-360	360-420	>420
P8 fat depth (mm)	<3	-0.90	-0.40	-0.30	-0.60	-0.80	-1.00
	3-6	-0.60	-0.20	-0.10	-0.40	-0.80	-1.00
	6-22	-0.30	-0.10	0.00	-0.20	-0.80	-1.00
	22-32	-0.60	-0.20	-0.10	-0.40	-0.80	-1.00
	>32	-0.90	-0.80	-0.80	-0.80	-1.00	-1.00

Carcass weight penalties were applied to both small (<240 kg) and large (>320 kg) carcasses as the retail cuts were too small or large, respectively, for standard portion sizes. Penalties were applied if the carcass was too lean, due to the increased risk of cold shortening occurring during the chilling process resulting in tough meat (Savell *et al*., 2005). Carcasses that were too fat also incurred penalties due to the cost for trimming (low yield).

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Grid plus Eating Quality Premium GEQ

A grid utilising an MSA index score between 54-61 was used as the ‘reference grid’ because it represents most commercial carcasses, reflecting the public grids.

Industry grids often cover three levels of MSA index plus eating quality guarantee fail. For the purposes of this study a fourth level was included giving:

1) MSA index 54-61 grid price \$5.90/kg HSCW;
2) fail MSA index <54 -\$0.90/kg.
3) MSA index >61-64 +\$0.10/kg;
4) MSA index >64-67 +\$0.20/kg; and
5) MSA index >67 +\$0.30/kg

The extra grid (>67) was included to cater for the high eating quality results of this research dataset. A failed MSA carcass would have been given the most severe penalty as its meat would be unsatisfactory and should be slashed to trim for manufacturing, thus it would be penalised to cow-beef prices but no carcasses herein required this penalty. The market signals from this price structure guide producers to maximise eating quality.

2.4 Continuous price

Yield Only –No Eating Quality Premium No optimum YO

For simplicity, it was assumed the average wholesale meat price across all primal cuts, including trim adjusted to 85% Chemical Lean (CL), was \$10.00/kg. Each cut and trim were weighed, multiplied by \$10 and then summed to give total carcass saleable meat value (\$). Carcass price (\$/kg) was then simply total carcase value (\$) divided by HSCW (kg). Thus, by definition, the yield only prices (mean \$6.84, range \$6.12-7.50) were exactly one tenth of the SMY.

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Given this price was the most simply calculated, it was taken as the base so all others were adjusted to have the same total carcass value as YO. Prices were then calculated as value divided by HSCW. As HSCW was not perfectly normally distributed, the mean of prices varied slightly for the different scenarios.

Yield plus Eating Quality Premium No optimum YEQ

MSA willingness to pay studies (Lyford *et al.*, 2010) indicate that consumers are willing to pay a premium at retail of 50% per MSA star rating as eating quality goes down to 2* ($10/kg) from 3* ($20/kg) or up to 4* ($30/kg) and 5* ($40/kg). At wholesale these prices would each be halved ($5, $10, $15 & $20 respectively). Given there are 16 MQ4 scores per MSA star rating, at wholesale the eating quality premium would be $5/kg per 16 MQ4 score units ($0.3125/kg/unit). Thus, the price for each cut was then calculated as $10 + 0.3125 × MQ4 score above the mid-point of MSA 3*, MQ4 score 57.5. Each cut weight was multiplied by its price to give cut value, while trim value was given $5/kg, and carcass value was calculated as the sum of all cut and trim values. Again, carcass price ($/kg) was simply value ($) divided by HSCW (kg).

Optimum HSCW & P8 YOO & YEQO

The price grid (Table 2), clearly indicates an optimum carcass weight. For HSCW, a quadratic function was fitted to the mid points of the grid cells from 200 to 420 kg for the optimum P8 (6-22 mm).

$$\text{Discount} = -\,4.228 + 0.03151 \times \text{HSCW} - 0.00005815 \times \text{HSCW}^2$$

Similarly, for P8 a quadratic function was fitted to the mid points of the grid cells from 0 to 32 mm for the optimum HSCW (240-320 mm).

$$\text{Discount} = -\,0.3231 + 0.04273 \times \text{P8} - 0.001283 \times \text{P8}^2$$

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These functions were used to calculate a discount or premium for carcasses of different HSCW and P8 and indicate optimums at 270.9 kg HSCW and 16.6 mm P8.

All price models were adjusted to the same mean carcass value ($2,278.30 per 333.1 kg) to allow comparison. This adjustment was chosen so that the models could be compared without affecting the total value of all carcasses, thus ensuring no bias for or against the producer or processor. This adjustment does not affect the variation in the value of carcasses though has a small effect on the mean and variation of prices. The YO price model was used as the base for this adjustment given the simplicity of price ($10/kg saleable meat), the mean YO price was $6.84/kg and others are presented (Table 3).

2.5 Statistical analysis

To describe carcasses multiple regression models were fitted to each pricing model. To contrast the effect of different sets of descriptors the following regression models were fitted:

1. HSCW linear and quadratic (to allow for optimum weight)
2. #1 plus P8 linear and quadratic (to allow for optimum fat)
3. #2 plus EMA and MB;
4. #3 plus SMY.

Quadratic terms for HSCW and P8 along with the interaction of their linear covariates (HSCW x P8) were fitted to grid and optimal price models, but not to YO or YEQ price models.

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3 Results

The summary of price data, amount of variation as determined by R^2, and the amount of prediction error for each model (RMSE) is presented in Table 3. It must be noted that SMY, by definition, explains all the variation of the YO model. This is due to the YO price being calculated as a single price ($10) multiplied by the weight of saleable meat, then divided by HSCW so price is completely a function of SMY. This is also responsible for the zero value of RMSE, as there is again, by definition, no error in the prediction model.

Table 3. Summary of prices and variation explained (R^2) in six prices by different explanatory models.

Price Model	GO	GEQ	YO	YEQ	YOO	YEQO
Mean	6.75	6.75	6.72	6.72	6.74	6.74
Minimum	6.16	6.12	6.26	6.05	5.60	5.88
Maximum	7.12	7.16	7.31	7.31	7.40	7.40
SD	0.367	0.333	0.240	0.210	0.380	0.310
Prediction model R^2						
1. Optimum HSCW	78	75	0.8*	6*	50	45
2. + Optimum P8	80	77	13*	9*	66	60
3. + EMA + MB	81	80	32	24	72	66
4. + SMY	81	80	100	94	100	97
Prediction model RMSE						
5. Optimum HSCW	0.174	0.169	0.240	0.204	0.272	0.232
6. + Optimum P8	0.169	0.164	0.226	0.202	0.226	0.201
7. + EMA + MB	0.167	0.155	0.201	0.187	0.206	0.187
8. + SMY	0.167	0.154	0	0.052	0	0.052

* optimum HSCW ($HSCW^2$) and P8 ($P8^2$) were not fitted to the YO or YEQ price models. All prices ($/kg) adjusted to the same total carcass value ($).

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HSCW and P8 (prediction model 1 and 2), as well as optimum HSCW and P8, are able to explain majority of the variation (R^2 > 75%) for the GO and GEQ price models, which is a slight reduction compared to the previous analysis. Again, there is negligible improvement within this analysis when EMA and MB (prediction 3) and SMY (prediction 4) are included within the prediction models. Another notable difference between the 2 analyses is the increase in value of RMSE for each prediction model using the GO and GEQ price models. Where the price is based on actual saleable meat yield, EMA and MB between 6 – 19% of the variation over and above the optimum weight and fat (prediction 3 vs 2). Addition of SMY (prediction 4) was able to explain 31 – 70% more variation than prediction 3 alone. The explanation of variation is accompanied by RMSE values ranging from 0 (prediction 4 for YO and YOO prices) to 0.240 (prediction 1 for YO price), showing some accuracy for the predictions.

Table 4 presents the correlations between traits and prices. All carcass values are highly correlated (>0.83) with HSCW, which is as anticipated. HSCW is also moderately correlated with EMA (0.47), while P8 fat (0.29), IMF (0.17) and MB (0.19) are only slightly positively correlated. The correlation of HSCW and SMY is only just measurable as a negative correlation. HSCW is also only slightly correlated YEQ (0.25), while being highly negatively correlated with both grid prices (GO & GEQ, >0.75) and moderately negatively correlated with YOO and YEQO (>0.45). The relationship between YOO and YEQO is very strongly correlated (R^2 = 0.94), which is significantly better than the value determined in the previous analysis. There is very little correlation (<0.15), positively or negatively, between the grid prices and the prices based on saleable meat yield (YO) or an eating quality premium (YEQ). When the optimum prices were applied on the grids, the correlations are moderately positive (>0.55), demonstrating again that the current grids are not able to describe the variation seen in meat yield and eating quality.

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Table 4. Correlations between traits, prices and carcass values

Trait	HSCW	P8	EMA	IMF	MB	SMY	GO	GEQ	YO	YEQ	YOO	YEQO
HSCW												
P8	0.29											
EMA	0.47	0.03										
IMF	0.17	0.27	-0.12									
MB	0.19	0.27	-0.11	0.996								
SMY	-0.09	-0.36	0.35	-0.37	-0.35							
Price												
GO	-0.82	-0.27	-0.27	-0.14	-0.15	0.15						
GEQ	-0.79	-0.21	-0.28	-0.03	-0.05	0.11	0.99					
YO	-0.09	-0.36	-0.35	-0.37	-0.35	1	0.15	0.11				
YEQ	0.25	-0.09	0.44	0.06	-0.09	0.84	-0.12	-0.10	0.84			
YOO	-0.59	-0.43	0.04	-0.38	-0.38	0.80	0.64	0.61	0.80	0.51		
YEQO	-0.48	-0.29	0.08	-0.13	-0.12	0.77	0.59	0.59	0.77	0.65	0.94	
Value												
GO	0.87	0.24	0.50	0.14	0.17	-0.13	-0.42	-0.39	-0.01	0.30	-0.37	-0.23
GEQ	0.89	0.28	0.49	0.21	0.24	-0.05	-0.47	-0.43	-0.05	0.30	-0.42	-0.26
YO	0.94	0.16	0.57	0.04	0.07	0.25	-0.75	-0.74	0.25	0.52	-0.31	-0.21
YEQ	0.97	0.24	0.54	0.17	0.20	0.14	-0.77	-0.74	0.14	0.49	-0.40	-0.26
YOO	0.83	0.08	0.60	-0.06	-0.03	0.43	-0.56	-0.56	0.43	0.65	-0.05	0.06
YEQO	0.89	0.18	0.57	0.12	0.15	0.29	-0.62	-0.60	0.29	0.62	-0.19	-0.03

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4 Discussion

This analysis was carried out to challenge the conclusions from a previous analysis, and questions raised about how realistic the dataset and results may have been. The results again show the measurement of yield adds substantial value, when value based continuous pricing strategies are utilised, and based on actual quality and quantity of saleable meat yield. There is a number of differences between the two analyses, however overall, the removal of the extreme carcasses in the form of the Jerseys and the Belgian Blues resulted in no discernible change in the results. The Belgian Blue crossbreds were removed due to their larger size, which may be a result of the myostatin gene (Fiems, 2012) and its known effect on certain muscles and cuts of the carcass, e.g. larger hindquarter cuts, reduced rib fat depth (McGilchrist *et al*., 2019). Research by McGilchrist *et al*. (2019) showed there was very little difference in cut distribution between carcasses of different muscling groups, except if the myostatin gene is carried. Carcasses of Belgian Blues can tend to be very lean, have extremely high carcass yield, low IMF, as well as other metabolic effects which may alter meat quality (Fiems, 2012). Albertí *et al*. (2008) detailed the significance in carcass weight, dressing percentage, fatness and *longissimus thoracis* area for Jersey carcasses when compared to 14 other breeds, with the Jersey being smaller in all areas, due to dairy breeds being predisposed to deposit more intra-abdominal fat. As a whole cohort Jerseys, tend to be slighter in size, which leads to a smaller carcass due to poor dressing percentages, as well as being nearly as lean as a Piemontese or Belgian Blue, so a characteristically lower in carcass value.

The main differences noted were small changes in correlation values, R^2 values and summary statistics of the prices and carcass data (Table 1, 3 and 4). That is, the differences were large enough to be noticeable, but small enough that it didn't make any impact on the results or their meaning. Within the carcass summary statistics, the measurable differences largely occur with changes in the mean values for each trait; +1.8 kg HSCW, +0.8mm P8, -0.06% IMF, -1.7 calc score MB, +0.7cm^2 EMA, -1.2% SMY and -1.8 units MSA. These differences could be considered to be very minimal in size when considered in comparison to an actual carcass.

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That is, these differences could potentially not be noticed within an average day at any given abattoir. There is very minimal research published covering how much variation is typically seen within an abattoir, so there is no way to verify whether this dataset is reflective of that variation.

As the results are unchanged for the data set with or without the ‘extreme’ carcasses, it raises the question whether the current data set is reflective of what an abattoir would actually see on a given day. The data set does not have any ungraded carcasses under MSA and possesses carcasses of various quality, with a large amount favouring higher MSA scores. MSA predicts the eating quality of individual cuts, based on multiple inputs available at grading (McGilchrist *et al*., 2019), therefore can be effected by multiple factors, some of which may be subjectively measured. Another point area which may need to be explored further is the calculation of the MSA Index that was carried out in the beginning. The MSA score used within the analysis is composed of all the score from each cut for its best suited cooking method. McGilchrist *et al*. (2019) found a score different of 10.5 points from best to worst cooking method, however as long as a constant combination was used it had little effect so the most common cooking method was used. Therefore, the index score may not actually be reflective of the true score, and by default true carcass value, for this reason as only the best cooking method was used.

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