The value of muscle score in beef cattle auction markets

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Abstract:

There is an increasing emphasis in Australia on finding ways to improve retail beef yield, but no current way to commercially measure retail yield. However there is a strong link between muscle score of the live animal as assessed in live cattle markets and subsequent meat yield measurements. Is there a credible value for muscle score in live cattle markets, and does it reflect the implied value of increased retail yield? In this paper these questions are investigated using price data from some 550 lots of male cattle sold at Wagga Wagga saleyard during the period July 2010 to June 2011. Two different types of hedonic models are applied and tested against each other. The premium for muscle score seems to have stayed at around 12-14 per cent of the base price after the initial jump from 7.5 per cent in 1990, although for particular categories of animals, interactions between muscle score, fat score and age are important, and premiums and discounts are more like 5-6 per cent of the base price.Premiums and discounts for muscle score evident in cattle saleyard prices are over-estimates of the eventual increase in retail value, according to the assumptions made in this paper.

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Background

Following years of debate, in the early 1970s the Australian cattle industry proposed a beef carcase classification system based on the objectively measured characteristics of sex, age, weight and fat depth. However implementation was slow, partly "because beef is a complex product, with many interrelated characteristics influencing its value." (Porter and Todd 1985, p.2). Irregular, non-uniform and non-independent market reporting of cattle sales was also an issue in some regions. Prompted by the cattle market crash of 1974, a number of parliamentary and industry inquiries (see for example, Prices Justification Tribunal 1978) recommended the establishment of independent market reporting of live cattle auctions across Australia. These Livestock Market Reporting Services (LMRS) were set up by the various state meat authorities or relevant government departments in the late 1970s and early 1980s. There was considerable debate about which of the potential cattle characteristics to include in the reports and most of the LMRS agencies restricted the number of characteristics to those that were included in the objective classification scheme and which they could be confident were differentially evaluated by buyers – age, sex, weight and fat depth. However it was recognized that a range of other data could be considered potentially relevant in determining cattle prices at auction, such as type of feeding regime, type of breed, area of origin, presence of horns, order of sale, number of head in a lot, etc.

A number of research studies were undertaken in the then Bureau of Agricultural Economics and elsewhere (see for example, BAE 1981, Hogan and Todd 1979, Park 1979, Naughtin 1980, Naughtin and Holland 1982, Hall 1981, Todd and Cowell 1981, Porter and Todd 1985) to assist in selecting appropriate cattle and carcase characteristics to report on, in assessing the accuracy of the market reporting staff and in evaluating the overall efficiency of price discovery in cattle and carcase markets. Some of these studies included only the reported characteristics, while others collected and assessed some of the other potential explanatory variables.

In an influential series of papers, Christine Williams and colleagues (Williams 1989, Williams, Longworth and Whan 1989, Williams, Rolfe and Longworth 1993) reviewed these past studies and found that the results were often inconsistent (Williams et al. 1993, Table 1, p.171). Following a survey of Queensland wholesalers and processors to determine which characteristics were important to buyers, they designed an experiment at two major Queensland cattle auction centres where data on some 1500 cattle sales were collected. These data included those characteristics regularly reported by the LMRS and other characteristics not reported by the LMRS. Based on their interviews with buyers, they hypothesized that muscle score would add considerably to the information content of the LMRS reports. They did indeed find that muscle score, both on its own and interacting with weight and fat score, was a highly significant characteristic in explaining price variation for all classes of cattle at both saleyard centres, and by far the most important additional characteristic explaining price variation to those already reported by the LMRS. Estimated premiums were around 4-9c/kg for a per unit decrease in muscle score, and estimated discounts were about the same value for a per unit increase in muscle score. Based on 1990 average cattle prices of 213c/kg dcw (ABARES 2013), or approximately 117c/kg lwt at typical dressing percentages, these premiums and discounts amounted to around 3.5-7.5 per cent.

Recent Research Interest

Meat yield is a key driver of profitability in beef production and processing under current selling and pricing systems. Across the whole Australian beef industry it is estimated that meat yield contributes around 80 per cent to profit while meat quality contributes only 20 per cent on a per carcase basis (Alford et al. 2009). While R&D on aspects of meat quality has drawn much of the recent attention, in particular the development and implementation of Meat Standards Australia (Griffith and Thompson 2012), there has been ongoing and growing interest in improving meat yield.

Meat yield per animal can be increased in the breeding herd by investing in particular breed types known to have higher meat yields or by selecting sires within breeds that have high Estimated Breeding Values (EBVs) for meat yield traits. Much of the research focus has been on these genetics and genomics avenues, for example using breeding stock with the Myostatin deletion (double muscling) gene (Alford et al. 2009, McKiernan et al. 2006).

However, processors and retailers want high retail beef yield carcases on their chains today. If the market was efficient producers would offer live animals for slaughter with high retail yields and be paid on this basis. But retail meat yield is a trait that is difficult and costly to assess, and cannot accurately be done on the live animal. Buyers seeking animals that will produce high retail yields after slaughter use muscle score of the live animal as a predictor of retail beef yield.

Muscle score describes the shape of cattle, after allowing for the influence of fatness. It is the degree of "thickness" or "convexity" of an animal relative to its frame size, after adjusting for fatness. There are five muscle score categories: A, very heavily muscled, to E, lightly muscled. Most British breed slaughter steers would be C, European breed types and their crosses would be B while most dairy breed types would be D or E. McKiernan (2001, 2002, 2007, 2011) provides details on muscle scoring of cattle, including an estimate of the distribution of muscle scores across slaughter steers in NSW. Muscle score is now a well established characteristic in all cattle saleyard auction and beef carcase auction reports (now known as the National Livestock Reporting Service (NLRS) and operated by Meat and Livestock Australia (NLRS 2012)). It should be noted that muscle score is different from other measures of cattle shape such as conformation and butt profile. The latter is reported in over-the-hooks market reports.

A number of research studies have examined the relationships between muscle scores on the live animal and meat yield from the carcase. Perry et al. (1993a,b) and Perry and McKiernan (1994) found that in a sample of 156 steers of mixed breeds, at the same liveweight and fat depth, each increase in the live animal muscle score was accompanied by a 1.7 per cent increase in dressing percentage and a 1.5 to 1.7 per cent increase in saleable meat yield when expressed as a percentage of carcase weight.

Café et al. (2006) compared two sets of steers, one the progeny of parents selected on the basis of high muscle score and the other the progeny of parents selected on the basis of low muscle score. The high muscling steers produced significantly less fat, greater eye muscle area and a higher dressing percentage than the low muscling steers, and a difference in retail beef yield of 1.2 percentage points, but this difference was not statistically significant.

In further work with these same herds selected for high or low muscling, Cafe et al. (2012, Table 12) found a significant difference of 0.8 percentage points in dressing percentage and 0.7 percentage points in meat yield between low (67.5 per cent) and high (68.2 per cent) muscle lines. However there was considerable individual variation in muscle score within the three selection lines, and the full muscle score range (A-E) was represented across the 228 steers at feedlot entry. When the carcase yield results were analysed with a muscle score covariate instead of the fixed effect of muscle line, an increase in muscling of one full muscle score led to a 1.2 per cent significant increase in retail meat yield.

A standard 260 kg domestic carcase has a saleable meat yield of 179 kg (Griffith and Thompson 2012, Table 3), or 68.8 per cent. At midrange dressing percentage of 55 per cent (McKiernan 2001, Table 3), the implied liveweight is 475kg. The retail value was $9.76/kg in 2011 across all saleable meat (Griffith and Thompson 2012, Table 1f). Therefore a 0.8 per cent increase in dressing percentage plus a 1.2 per cent increase in retail beef yield is worth $42.47 per carcase or 16/kg across all of the 183kgs of saleable meat.

McKiernan et al. (2006) used the rule of thumb that one muscle score change between a low muscle herd (D) and a high muscle herd (C) was equivalent to 1.5 percentage points in retail beef yield, or approximately 2.5 per cent. Using the above data, this would again imply an extra $42.26 per carcase or about 16c/kg.

In summary, there is an increasing emphasis on finding ways to improve retail beef yield. Currently, there is no way to commercially measure retail yield but there is evidence of a strong link between muscle score of the live animal and subsequent meat yield measurements. A relevant question is whether there is a credible value for muscle score in live cattle markets, and does it reflect the implied value of increased retail yield? Unfortunately, available estimates are dated. In the study referred to above, Williams et al. (1993) suggest that penalties per unit decrease in muscle score could be as high as 9c/kg lwt for steers and average around 4c/kg lwt for other types of cattle based on 1990 Queensland cattle prices. Griffith et al. (1998) using cattle auction data from Wagga Wagga saleyard over the period July 1995-June 1997 suggest a discount of around 13c/kg lwt for muscle score D cattle relative to muscle score C cattle. McKiernan (2002) in an analysis of cattle saleyard prices found a 15 to 20c/kg lwt benefit per muscle score, and this premium was linear between scores. With the most recent estimate of the muscle score premium or discount at least 10 years old, it is time to update our knowledge of this important market signal.

The above discussion suggests two main research questions: (a) do buyers differentiate between various types of cattle on the basis of a range of quality characteristics? And (b) in particular, do significant premiums and discounts occur for muscle score classes? Following, if such premiums and discounts do occur, are they sufficient for beef producers to meet market demands for different characteristics? The analysis which follows is aimed at answering these questions.

Model and Data

We can consider the research questions raised above using hedonic models as described in several previous studies of the Australian cattle market (Porter and Todd 1985, Williams, Rolfe and Longworth 1993, Griffith, Burgess and Davidson 1998). Related studies include Faminow and Gum (1986), Schroeder, Minert, Brazie and Grunewald (1988),Mullen (1995), Walburger (2002) and Hufton, Griffith, Mullen and Farrell (2009).

Hedonic Models

In this type of analysis we seek to explain differences in prices received for various types of cattle (say between lighter leaner animals and heavier more muscled animals) by observable differences in those characteristics which are expected to influence value in particular end uses (such as age, weight, sex, fat cover, muscle score, etc). Two hedonic price specifications have been proposed in the literature to estimate these sorts of models (reviewed by Mullen 1995). The first is the **absolute price** model:

(1) $P_i = \alpha P_r + \Sigma X_{ij} D_j + e_a$

where P_i is the price of the i^{th} class or type of cattle; P_r is the price of a reference type of cattle which has a given set of quality characteristics and which is selected to best reflect underlying supply and demand factors; α is the mean price transmission coefficient which reflects the extent to which a one unit change in the reference price is reflected in P_i; X_{ij} is the quantity of the quality characteristic j supplied by cattle type i; and D_j is the set of price differentials, away from the reference type, for a one unit change in the quality characteristic j. These differentials are coefficients estimated in the regression model and they can be positive (premiums, for a more-preferred characteristic) or negative (discounts, for a less-preferred characteristic). If P_i is expressed in c/kg, then the differentials are also expressed in c/kg. The underlying hypothesis of the absolute price model is that the estimated premiums and discounts for quality differences are constant - the differentials are independent of price levels. An error term is added for estimation.

The second specification is the **relative price** model (Waugh 1928):

(2) $P_i/P_r = \beta + \Sigma X_{ij} D_j + e_r$

where the variables are as defined above except that β is the mean value of the relative price ratio, and the error term is different. Here, the differentials are not expressed in c/kg but in terms of percentage change, and the hypothesis is that the quality differentials are proportional to price - as prices rise the differentials expand, and as prices fall the differentials contract.

These two specifications may be tested against each other using non-nested J and JA tests as reviewed by Doran (1993).

Data

A number of specific data choices have to be made to implement the two model forms:

* **Selection of market**. The National Livestock Reporting Service reports on prices paid at a number of cattle saleyard auctions in each state and on estimated prices paid over-the-hooks by the major beef processing companies. Reports are provided each week. In this study, Wagga Wagga saleyards are chosen as the indicator market. Wagga is one of the largest New South Wales saleyards, cattle are sourced from a broad area of southern Australia and this market has been used previously as an indicator market for analyses of both cattle and lamb prices (Griffith et al. 1998, Hufton et al. 2009).

* **Selection of NLRS cattle quality characteristics**. The NLRS reports contain a variety of information including: age class, sex, fat score, muscle score, category weight, number of head, price in cents per kg lwt, cents per kg cwt and dollars per head (low, high and average for each), change from previous sale, and a code to indicate whether grainfed, dairy beef or pastoral cattle, and what type of buyer if not for immediate slaughter.

From this list a subset of quality characteristics was made available by the NLRS. The characteristics were age class (3 possible classes: vealer, yearling, grown cattle), liveweight weight class (7 possible classes: 0-200 kg, 200-280 kg, 280-330 kg, 330-400 kg, 400-500 kg, 500-600 kg and 600-750 kg), muscle score class (3 possible classes : MSB, MSC and MSD), fat score class (4 possible classes: FS2, FS3, FS4 and FS5), price in c/kg lwt (low, high and average for each class reported), and number of head for each sale class reported. All classes were specified to be male and no other codes were provided.

* **Selection of cattle types.** Based on the full set of quality characteristics provided, there are 252 possible cattle classes. However many of the possible cells are empty due to biophysical reasons (for example, a particular age category implies a limited set of weight categories) and many of the classes only have a few observations. It was decided to use all possible data points even if observations were limited. There are a total of over 11,000 cattle represented in this data set.

* **Selection of reference type.** One of the possible cattle types has to be chosen as the reference type. Based on examination of sale numbers for each type, the reference type selected was grown steer, 400-500 kg lwt, MSC, and FS3.

* **Selection of time period.** To obtain price series which covered different seasons and different market conditions, the time period selected was from 1 July 2010 to 30 June 2011. This resulted in a maximum number of 48 weekly sale observations for each of the cattle types. When the reference price in a particular week was paired with the prices of all other available cattle types in the same week, the total number of observations is 550.

Implementing the Model

For each of the available non-reference cattle types, the price series for that type (P_i), the reference price series (P_r) and the number of head for each P_i were entered as continuous series and the series for the quality characteristics were entered as dummy variables, where the dummy took the value zero if it was identical to the reference type and one if it was different. Thus there were two dummy variables for age (VEAL, YEARLING), six dummy variables for weight (wt000200, wt200280, wt280330, wt330400, wt500600, wt600750), two dummy variables for muscle score (MSB, MSD) and three dummy variables for fat score (FS2, FS4, FS5). The data set was then organised in panel format with the possible observations on each of the non-reference cattle types stacked vertically. This gave an estimation sample of 550 observations. Eleven monthly dummy variables were constructed and added to account for variations in pasture growth patterns, cattle breeding cycles and seasonality in demand for different types of meat, both domestically and in export markets. Interaction terms between the quality characteristics were constructed and added as appropriate. There were 23 potential interaction terms between the non-reference class characteristics. We also include the number of head in each sale lot (HEAD) as a fixed effect to account for the fact that different cattle classes have different numbers of observations.

The full specifications of the absolute and relative price models are therefore of the general form:

(3) P_i = f (P_r, VEAL, YEARLING, wt000200, wt200280, wt280330, wt330400, wt500600, wt600750, MSB, MSD, FS2, FS4, FS5, monthly seasonal dummies (11), characteristic interactions (23), HEAD), and

(4) P_i/P_r = f (Constant, VEAL, YEARLING, wt000200, wt200280, wt280330, wt330400, wt500600, wt600750, MSB, MSD, FS2, FS4, FS5, monthly seasonal dummies (11), characteristic interactions (23), HEAD).

Seasonal dummy variables and interaction terms that were consistently not significant across various specifications were omitted to conserve degrees of freedom. The omitted variables varied slightly according to whether the absolute or relative price model was estimated.

Data Summary Statistics

The summary statistics for the final data set are given in Table 1. As expected, the reference price series (ref) has a lower mean and less variability than the P_i series (price), since the latter contains a wider range of cattle types. The ratio variable used in the relative price model therefore has a mean greater than one and quite high variability. The means of the dummy variables reflect the proportions of those characteristics in the final data sets. The data set does not appear to be biased across any of the quality measures, with the exception of the very light weight class and the highest fat score class which each have just one observation. Lot size ranges from 1 to 403, with an average around 20.

[Table 1 about here]

Figure 1 shows the relationship between the reference price and the other prices at Wagga saleyard over the available 550 observations. These are sorted by sale date, so the reference price is fixed for each sale date and the other prices reflect all of the other cattle types sold on that date. The whole array of prices generally moves together in a broad seasonal pattern, but there is considerable short term variability in all prices.

[Figure 1 about here]

4. Estimation Results

The estimation strategy for each of the absolute and relative price models was as follows:

- The base model was estimated that contained just the price terms and the characteristic dummy variables.
- Then, the base model was augmented sequentially with the set of seasonal dummy variables, with the set of characteristic interactions, and then with both sets, and F and Chi Square statistics were calculated to test for the inclusions.

- The preferred model was then subjected to specification tests including whether linear or log versions better fitted the data.
- The preferred absolute price and relative price models were then compared to see which model better fitted the data.

The Absolute Price Model

The summary data from each of the absolute price models and the test statistics for including the various sets of explanatory variables are shown in Table 2. All 11 seasonal dummy variables and all 23 interaction terms were included to begin with, and then those that were consistently non-significant were excluded. Based on these results, the preferred model is the base model plus both the significant characteristic interaction terms and the significant seasonal dummy variables.

[Table 2 about here]

The RESET test for mis-specification is uniformly non-significant, and the R^2 and log likelihood values indicate an increasing level of explained variance as the two sets of additional variables are included with the base model, one by one and then jointly. The preferred absolute price model has the highest adjusted R^2, the lowest log likelihood and CHI and F test values which indicate it is superior to all other options. It is shown in Table 3.

[Table 3 about here]

Here, over 83 per cent of the variation in the price variable can be explained by the chosen variables. This indicates that even at the saleyard level, differentiation between cattle types is based primarily on end uses as predicted by quality attributes and the other factors that influence price are less important, once the overall level of price is accounted for. Further, as shown in Figure 1, the prices of the various characteristic classes all tend to move together. The RESET test shows good specification and while the Durbin Watson test indicates significant autocorrelation, this is expected given the temporally constructed nature of the data set (as also shown in Figure 1).

Based on the estimated coefficient of the reference price variable, a 10c/kg change in the price of the reference class is reflected in a 9.8c/kg change in the prices of the other livestock classes on average. Based on the estimated mean values of the two series, this equates to a price transmission elasticity of around 0.95. The head variable is significant and positive, indicating an increase of around 0.4c/kg in price for every 10 head increase in lot size, of the non-reference cattle types.

Almost all of the quality characteristics are highly significant by themselves. The veal and yearling age dummy variables are both positive and significant and indicate premiums of between 10 and 15c/kg for younger cattle, all other attributes the same. All but the heaviest weight dummy variables are significant and surprisingly all positive and this means that if the weight class was to either decrease or increase from that of the reference class, all other attributes the same, there would be a significant premium from doing so of up to 28c/kg. The coefficient for the MSB variable is significant and positive, suggesting a premium of around 33c/kg for a MSB animal relative to a MSC animal, all other attributes the same, while the coefficient for the MSD variable is significant and negative suggesting a discount of around 16c/kg on average relative to a MSC animal. All of the fat score coefficients are significant and negative suggesting discounts of around 17c/kg for very lean animals and discounts of almost 30c/kg for very fat animals, all other attributes the same. There is a small discount of around 4c/kg for FS4.

The data also suggest significant interactions between some of the carcase quality characteristics, in particular age, muscle score and fat score. While young cattle and highly muscled cattle are shown individually to have premiums in the market, when these characteristics interact the premiums are reduced. For example, there is a premium of 15c/kg for vealers plus a premium of 33c/kg for MSB, but then there is a discount of 24c/kg due to the interaction, so the net premium is 24c/kg for highly muscled vealers. For highly muscled yearlings, the net premium is also 24c/kg. On the other hand, yearlings that also have MSD have a net discount of 16c/kg, so being younger does not overcome light muscling.

Low fat cover is discounted against on average by 17c/kg, but in young cattle with FS2 this discount is offset by the interaction terms and a net premium for young age prevails, 16c/kg for vealers and 6c/kg for yearlings. Finally, those animals that are both lightly muscled and have low fat cover are further discounted by some 12c/kg, leading to a net discount of 45c/kg, while there is a net premium of around 14c/kg for those animals that are lightly muscled but have FS4.

Individually the monthly variables that were consistently significant suggest discounts of around 5-10c/kg for late summer and late winter relative to December.

The specification tests for functional form were inconclusive as shown in Table 4, with both linear and log models being rejected in favour of the alternative. The linear model was retained for ease of interpretation.

[Table 4 about here]

The Relative Price Model

The relative price model was estimated using the same procedures as for the absolute price model. Again, both R^2 and log likelihood statistics improve as the seasonality and interaction variables are added, and based on the test statistics reported in Table 5, the preferred model included both significant seasonal effects and significant interactions between the various animal characteristics.

[Table 5 about here]

The preferred relative price model is shown in Table 6. Some 76 per cent of the variation in the ratio of P_i to the reference price is explained by the estimated model. Almost all of the quality characteristics are individually highly significant. The four lighter weight dummy variables are significant and positive, and this means that if the weight class was to decrease from that of the reference class, all other attributes the same, there would be a significant premium from doing so of between 4 and 16 per cent. If the weight class was to increase from that of the reference class, all other attributes the same, there would be a significant premium from doing so of about 4 per cent. The coefficient for the MSB variable is also significant and positive, suggesting a premium of around 12 per cent for a MSB carcase relative to a MSC carcase, all other attributes the same, while the coefficient for the MSD variable is significant and negative indicating a 7 per cent discount for the lighter muscled animals. All the fat score variables indicate discounts for both too fat and too lean, up to 14 per cent.

[Table 6 about here]

Looking at significant interactions between the carcase quality characteristics, well muscled lighter animals are discounted by between 7 and 9 per cent or around 15c/kg lwt, so the net MSB premium for those classes is around 10c/kg lwt. Further, yearlings that also have MSD are further discounted by over 6 per cent or almost 13c/kg lwt, and those animals that are both lightly muscled and have low fat cover are also discounted by some 6 per cent or 12c/kg lwt. The net MSD discount is therefore somewhat larger, near 27c/kg lwt, for those types of animals., The seasonal dummy variables are highly significant as a group and follow quite a similar pattern as in the absolute price model. All significant coefficients suggest a discount away from the December base value of between 4 and 6 per cent. Finally, the number of head variable is positive and significant and suggests that a 10 head increase in lot size would improve price by 0.2 per cent.

The specification tests for functional form were again inconclusive as shown in Table 7, and again the linear model was retained.

[Table 7 about here]

Comparing the Preferred Absolute and Relative Price Models

A cursory comparison of Tables 3 and 6 suggests very similar patterns of significant variables across the two preferred models. The only real difference is in the characteristic interaction terms where some significant interactions evident in Table 3 are not replicated in Table 6, and vice versa. To select which preferred model is the best, they were formally tested against each other using J and JA tests. This involved transforming the preferred relative price model so that it had the same dependent variable as the preferred absolute price model (following Mullen 1995). The results are shown in Table 8.

[Table 8 about here]

Both test statistics rejected the null hypothesis that the absolute price model is the correct model, and both test statistics failed to reject the null hypothesis that the relative price model is the correct model, so the conclusion is that the relative price model provides a better explanation of premiums and discounts in Wagga Wagga saleyard beef prices due to quality attributes.

Summary and Conclusion

The linear version of the relative price model (Table 6) appears to best explain price behaviour in relation to quality characteristics in the Wagga Wagga cattle saleyard market. The key results are summarized below in Table 9.

[Table 9 about here]

The results indicate that different values do apply for different quality characteristics in the Wagga Wagga cattle auction market. All of the broad types of quality characteristics included in the preferred relative price model were important in explaining price variation and all but one of the individual quality characteristics were statistically significant. Further, the magnitude of the effects were in some cases large with estimated premiums and discounts of up to 15 per cent or up to 30c/kg lwt at the average reference class price. This is shown further in Figure 1 where for any given sale there is often a large price range in the non-reference classes of cattle, sometimes exceeding 50c/kg lwt. Finally, the preferred model explains around three quarters of all the variation in prices, indicating that the set of included variables in the NLRS reports cover the range of quality characteristics that buyers use to differentiate between various types of cattle on the basis of end use. The results of the preferred alternative absolute price model are also included in Table 9 and it is evident that the magnitude of the estimated premiums and discounts is very similar across the two models.

In relation to the specific characteristic of muscle score, there are significant premiums and discounts for the different muscle score classes. The coefficient for the MSB variable suggests a premium of around 12 per cent for a MSB carcase relative to a MSC carcase, all other attributes the same, or almost 25c/kg lwt at the average reference class price. However, well muscled lighter animals are discounted by between 7 and 9 per cent or around 15c/kg lwt, so the net muscle score B premium for those classes is around 10c/kg lwt. Alternately, the coefficient for the MSD variable indicates a 7 per cent discount for the lighter muscled animals, all other attributes the same, or around 14c/kg lwt. Further, yearlings that also have MSD are further discounted by over 6 per cent or almost 13c/kg lwt, and those animals that are both lightly muscled and have low fat cover are also discounted by some 6 per cent or 12c/kg lwt. The net muscle score D discount is therefore somewhat larger, near 27c/kg lwt, for those types of animals. Thus MSB animals have a premium of between 10 and 25c/kg, while MSD animals have a discount of between 14 and 27c/kg. The impacts are generally similar in the preferred absolute price model although there are no weight interactions evident in that model and the base premium for MSB over MSC is somewhat larger at 33c/kg lwt.

Have premiums changed over time? Recall the previous estimates: Williams et al. (1993) found penalties per unit decrease in muscle score could be as high as 9c/kg lwt for steers and average around 4c/kg lwt for other types of cattle based on 1990 Queensland cattle prices; Griffith et al. (1998) suggest a discount of around 13c/kg lwt for MSD cattle relative to MSC cattle using 1995/97 prices; and McKiernan (2002) found a 15 to 20c/kg lwt benefit per muscle score using 2001 prices. So in terms of nominal absolute premiums and discounts, without interaction terms, the value of a muscle score seems to have increased over the past 20 years from say 9c/kg to 25c/kg lwt for a grown steer; but when underlying price levels over the same period are accounted for, the value seems to have stayed at around 12-14 per cent of the base price after the initial jump up from 7.5 per cent in 1990. For particular categories of animals however, interactions between muscle score, fat score and age are important, and premiums and discounts are more like 5-6 per cent of the base price.

Does the c/kg premium for MSB relative to MSC found above relate closely or not to the estimated increase in carcase value due to an increase in retail beef yield? From earlier in the paper we have estimates of the increased value of greater yield and dressing percentage of around 16c/kg on a cwt basis for an increase in one muscle score. From the results above, the c/kg premium for MSB relative to MSC is between 10 and 25c/kg lwt. Converting these values to dcw, we have saleyard estimates of 18 to 45c/kg vs retail estimates of 16 c/kg. Even if the retail value estimate was considered very conservative, it seems the premiums and discounts for muscle score evident in cattle saleyard prices are over-estimates of the eventual increase in retail value, according to the assumptions made in this paper.

Whether the estimated premiums and discounts for the various quality characteristics provide sufficient incentives for beef producers to change their production systems to meet market demands for different characteristics will depend on the nature and flexibility of the existing system, the feasible options available and the attitudes of the producer. At least this type of analysis provides an indication of the potential revenue available from making a change that can be set against the expected costs of implementing the change.

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Figure 1. The reference price (grown steer, 400-500kg lwt, msc, fs3) and other prices at Wagga Wagga saleyards, 2010-2011

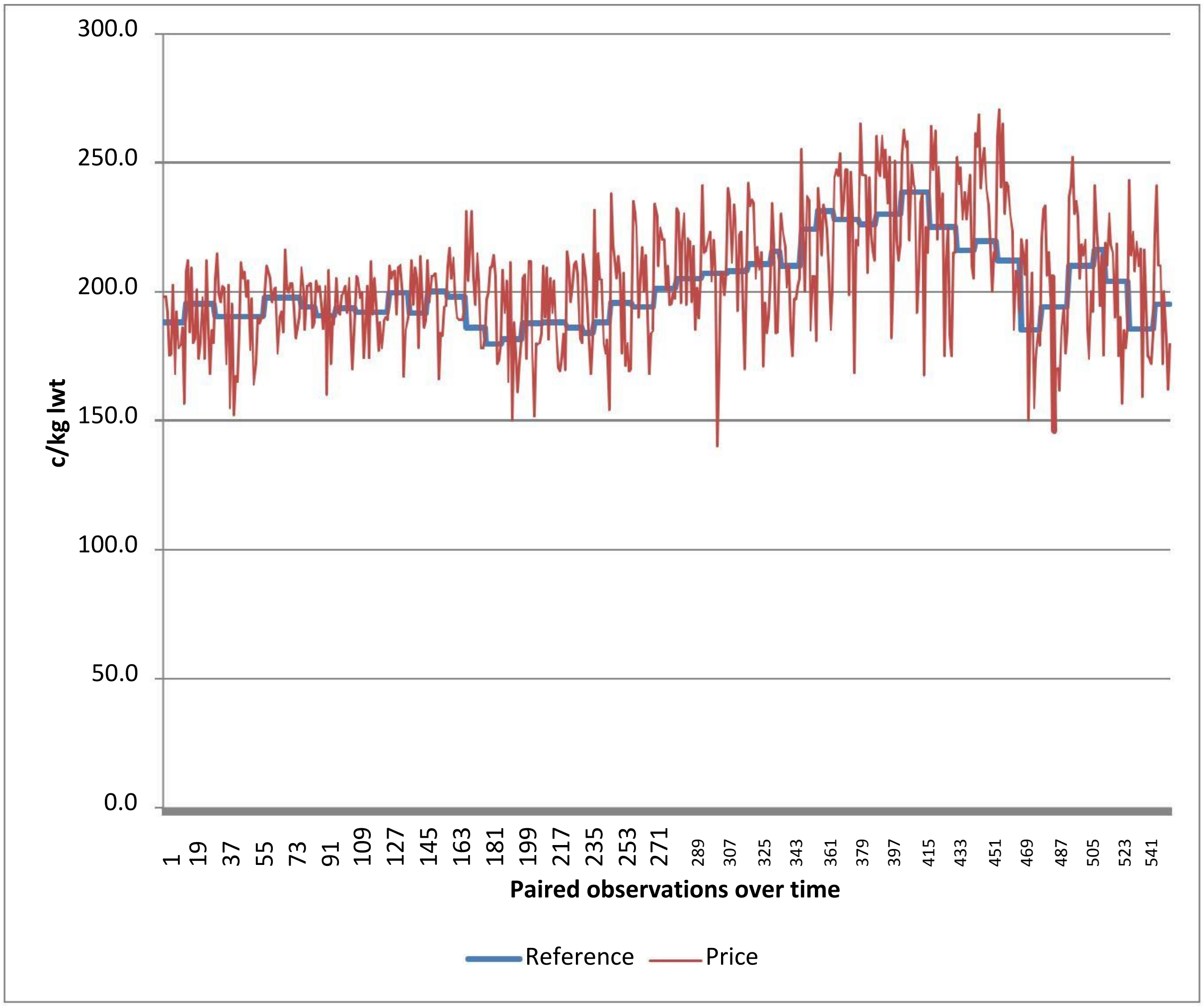

Table 1.Wagga Wagga saleyard data summary statistics, July 2010-June 2011

Variable	Mean	Std Dev	Minimum	Maximum
PRICE	200.47	23.231	140.00	270.60
REF	193.69	14.099	175.90	227.60
PRATIO	1.036	0.099	0.702	1.355
VEAL	0.291	0.455	0.000	1.000
YEARLING	0.369	0.483	0.000	1.000
STEER	0.340	0.474	0.000	1.000
WT000200	0.002	0.043	0.000	1.000
WT200280	0.056	0.231	0.000	1.000
WT280330	0.167	0.374	0.000	1.000
WT330400	0.270	0.443	0.000	1.000
WT400500	0.258	0.438	0.000	1.000
WT500600	0.098	0.298	0.000	1.000
WT600750	0.149	0.357	0.000	1.000
MSB	0. 147	0.355	0.000	1.000
MSC	0. 751	0.433	0.000	1.000
MSD	0.102	0.303	0.000	1.000
FS2	0.362	0.481	0.000	1.000
FS3	0.465	0.499	0.000	1.000
FS4	0.171	0.377	0.000	1.000
FS5	0.002	0.043	0.000	1.000
HEAD	20.09	34.35	1.000	403.00

Table 2. Absolute price models

Model	Adj. R^2	RESET2	Log Likelihood	F-statistic for inclusion	Chi Square statistic for inclusion
Base model	0.777	1.99	-2090.88	-	-
Base model plus significant seasonality	0.808	0.08	-2045.75	F(6,529)= 15.72*	CHI(6)= 90.26*
Base model plus significant interactions	0.803	1.69	-2052.99	F(7,528)= 11.14*	CHI(7)= 75.79*
Base model plus significant seasonality plus significant interactions	0.831	0.05	-2006.94	F(7,522)= 11.30* F(6,523)= 15.89*	CHI(7)= 77.62* CHI(6)= 92.09*

Critical values at 5% are CHI(6)=12.59, CHI(7)=14.07, F(6,529)=F(6,522)=2.12, F(7,528)=F(7,523)=2.03.
* significant at 5%.

Table 3. Absolute price model with significant seasonal effects and significant interactions between characteristics

Variable	Estimated Coefficient	Standard Error	t-statistic	P-value
REF	0.984	0.008	125.914	[.000]
VEAL	14.936	2.553	5.849	[.000]
YEARLING	9.996	2.038	4.904	[.000]
WT000200	28.134	9.800	2.871	[.004]
WT200280	18.774	2.552	7.356	[.000]
WT280330	13.981	1.755	7.969	[.000]
WT330400	8.731	1.581	5.522	[.000]
WT500600	8.972	2.298	3.904	[.000]
WT600750	2.237	1.995	1.121	[.263]
MSB	32.775	9.972	3.287	[.001]
MSD	-16.353	2.559	-6.391	[.000]
FS2	-16.594	3.035	-5.468	[.000]
FS4	-3.832	1.845	-2.076	[.038]
FS5	-29.620	9.710	-3.050	[.002]
JAN	-5.870	1.491	-3.937	[.000]
FEB	-9.614	1.794	-5.358	[.000]
MAR	-5.488	1.516	-3.619	[.000]
JUL	-9.044	1.434	-6.306	[.000]
AUG	-6.933	1.411	-4.913	[.000]
SEP	-10.552	1.611	-6.550	[.000]
MSB*VEAL	-23.967	10.128	-2.366	[.018]
MSB*YEAR	-19.370	10.766	-1.799	[.073]
MSD*YEAR	-9.872	3.723	-2.652	[.008]
FS2*VEAL	18.116	3.710	4.883	[.000]
FS2*YEAR	13.374	3.356	3.985	[.000]
FS2*MSD	-11.780	4.104	-2.870	[.004]
FS4*MSD	6.407	4.047	1. 583	[.114]
HEAD	0.041	0.016	2. 589	[.010]

Adjusted R-squared = 0.831; Mean of dep. var. = 200.47; Durbin-Watson = 1.53 [<.000]; Ramsey's RESET2 = 0.05 [.831].

Table 4. Preferred absolute price model, specification tests

Absolute Price Model	JA test	J test
Ho: Linear is true	-448.3* (reject)	203.0* (reject)
Ho: Log is true	0.0030* (reject)	0.0048* (reject)

See Doran (1993). Critical values are normal t statistic values at 5%.

Table 5. Relative price models

Model	Adj. R^2	RESET2	Log Likelihood	F-statistic for inclusion	Chi Square statistic for inclusion
Base model	0.673	0.212	808.5	-	-
Base model plus seasonality	0.727	45.27*	860.6	F(6,529)= 18.42*	CHI(6)= 104.33*
Base model plus interactions	0.710	2.01	845.6	F(8,528)= Very large*	CHI(8)= 74.24*
Base model plus seasonality plus interactions	0.759	51.52*	898.6	F(6,522)= 18.48* F(8,522)= 9.65*	CHI(6)= 105.93* CHI(8)= 75.84*

Critical values at 5% are CHI(8)=15.51, CHI(6)=12.59, F(8,528)=F(8,522)=1.96, F(6,529)=F(6,522)=2.12.
* significant at 5%.

Table 6. Relative price model with seasonal effects and interactions between characteristics

Variable	Estimated Coefficient	Standard Error	t-statistic	P-value
C	0.986	0.008	131.285	[.000]
VEAL	0.073	0.013	5.641	[.000]
YEARLING	0.053	0.010	5.043	[.000]
WT000200	0.164	0.050	3.286	[.001]
WT200280	0.106	0.016	6.518	[.000]
WT280330	0.074	0.009	8.031	[.000]
WT330400	0.045	0.008	5.448	[.000]
WT500600	0.041	0.011	3.641	[.000]
WT600750	0.011	0.010	1.093	[.275]
MSB	0.122	0.029	4.221	[.000]
MSD	-0.072	0.010	-7.234	[.000]
FS2	-0.073	0.015	-4.921	[.000]
FS4	-0.015	0.008	-1.756	[.080]
FS5	-0.146	0.049	-2.969	[.003]
JAN	-0.036	0.007	-4.755	[.000]
FEB	-0.054	0.009	-6.002	[.000]
MAR	-0.037	0.007	-4.937	[.000]
JUL	-0.048	0.007	-6.521	[.000]
AUG	-0.038	0.007	-5.330	[.000]
SEP	-0.057	0.008	-7.010	[.000]
YEAR*MSD	-0.063	0.017	-3.650	[.000]
VEAL*FS2	0.082	0.019	4.433	[.000]
YEAR*FS2	0.055	0.017	3.308	[.001]
MSB*WT200280	-0.087	0.034	-2.558	[.011]
MSB*WT280330	-0.081	0.032	-2.528	[.012]
MSB*WT330400	-0.067	0. 031	-2.169	[.031]
MSD*FS2	-0.061	0. 021	-2.913	[.004]
HEAD	0.002	0. 001	2.454	[.014]

Adjusted R-squared = 0.759; Mean of dep. var. = 1.036; Durbin-Watson = 1.53 [<.000]; Ramsey's RESET2 = 51.52 [.000].

Table 7. Preferred relative price model, specification tests

Relative Price Model	JA test	J test
Ho: Linear is true	-4.64* (reject)	1.04* (reject)
Ho: Log is true	0.85* (reject)	0.96* (reject)

See Doran (1993). Critical values are normal t statistic values at 5%.

Table 8. Preferred relative price model vs preferred absolute price model

Absolute vs Relative Price Model	JA test	J test
Ho: Relative price model is true	-0.130 (do not reject)	0.023 (do not reject)
Ho: Absolute price model is true	0.998* (reject)	0.996* (reject)

See Doran (1993). Critical values are normal t statistic values at 5%.

Table 9.The relative price model, with significant seasonal and interaction effects

Variable, relative to the reference class+	Estimated coefficient	Implied c/kg premium or discount at the mean reference price (200.5 c/kg)	Premium or discount from the preferred absolute price model (Table 3)
Vealer	0.073	14.6	14.9
Yearling	0.053	10.6	10.0
Wt000200	0.164	32.9	28.1
Wt200280	0.106	21.3	18.8
Wt280330	0.074	14.8	14.0
Wt330400	0.045	9.0	8.7
Wt500600	0.041	8.2	9.0
Wt600750	0.011	(ns)	(ns)
MSB	0.122	24.4	32.8
MSD	-0.072	-14.4	-16.4
FS2	-0.073	-14.6	-16.6
FS4	-0.015	-3.0	-3.8
FS5	-0.146	-29.2	-29.6
Yearling*MSD	-0.063	-12.6	-9.9
Vealer*FS2	0.082	16.4	18.1
Yearling*FS2	0.055	11.0	13.4
MSB*Wt200280	-0.087	-17.4	-
MSB*Wt280330	-0.081	-16.2	-
MSB*Wt330400	-0.067	-13.4	-
MSD*FS2	-0.061	-12.2	-11.8

+ The reference class is grown steer, 400-500kg lwt, MSC, FS3.