Australian Journal of Agricultural Economics, Vol. 29, No. 3 (December, 1985), pp. 225-234

THE EFFECT OF CARCASS QUALITY ON BEEF CARCASS AUCTION PRICES*

DARRELL PORTER and MIKE TODD
Bureau of Agricultural Economics, Canberra, ACT 2601

Although meat industry representatives recognise a need for improvement in product description for livestock and meat, there is still considerable debate about which type of system should be adopted. The issue is usually considered in the context that improved product description could lead to improvements in efficiency in the marketing of livestock and meat (Hall 1984). It is argued that standardised and objective product description along the marketing chain could facilitate the transmission of price information on livestock and meat products and thereby improve the ability of livestock producers to service effectively the needs of consumers on the domestic and export markets (BAE 1981).

Little research into which characteristics are important in the determination of the price of beef carcasses in Australia has been conducted. Some of these carcass characteristics can be measured by objective methods, but others require subjective assessment. The characteristics are sex, age, weight, fat depth, meat colour, fat colour, shape, meat texture, fat texture, length, fat distribution, bruising, marbling, ribeye area and whether or not a beast has been grain fed. Objectively measurable factors, such as sex, age, weight and fat depth have been incorporated into the proposed carcass classification system. However, in previous research it has been suggested that some of the abovementioned subjective carcass characteristics are also important in determining price. An important issue arises as to the extent to which both objective and subjective characteristics are reflected in prices received by producers.

In 1972, the Australian Meat Board's Committee on Grading and Classification proposed that objective carcass classification based on the factors of sex, age, weight and fat depth be the basis for standardising meat product description (AMB 1972). The development of objective carcass descriptions has been slow, with the demand for classification varying, depending on the species. Objective pig carcass classification has been widely introduced and, associated with this, 'sight-unseen' pig carcass auctions are now conducted in all states except Tasmania and the Northern Territory. Objective product description for beef carcasses has not been widely adopted. Many commentators suggest that this is partly because beef is a complex product, with many interrelated characteristics influencing its value.

The aim is the determination of the set of factors which explains, to a large extent, the variation in beef carcass auction prices. This set may

* Mike Todd is now at the Australian Meat and Livestock Industry Policy Council. The authors wish to acknowledge the co-operation and assistance of the Western Australian Department of Agriculture, the carcass auction operators, the Australian Meat and Live-stock Corporation and the National Carcass Classification Supervisory Committee for funding the project. The authors also wish to thank Geof Watts and Ross Dunstan for their contribution to the quantitative analysis.

include both objective factors and those subjective factors which can be specified using visual aids, such as meat colour charts. These factors should be considered in any improved carcass description system.

As the two carcass auctions examined in this study supplied beef to the domestic market, the results of this study can be extended to the export market only if it is assumed that buyers in both markets desire the same carcass characteristics. Both the industry and the government accept that the current grading specifications do not adequately meet the diverse requirements of Australia's major export markets. Government regulations relating to meat have been changed from a subjective grade basis to a more objective basis. The objective characteristics to be used are sex, age, weight and fat depth. Allowance has also been made for other measures to be included in the trade descriptions at the option of the processor or exporter. Subjective carcass characteristics have been considered as optional criteria at this stage because of the problems of measurement and, hence, difficulty in monitoring. The results presented in this paper provide some evidence to support research currently being undertaken into the Australian meat industry.

Review of Previous Research

There is a substantial body of research relating to the factors which influence livestock price variation (see, for example, Keane and Riordan 1973; Fielder and Martinez 1974; Wittenburg 1977; Hogan and Todd 1979; Buccola 1980; Hall 1981; Todd and Cowell 1981). However, little research has been conducted into which characteristics are important in the determination of price of beef carcasses in Australia. This is largely because, as few carcass auctions are operating in Australia, it is difficult to obtain price data.

On balance, from the research available to date (Biggs 1975; Hall 1981; Todd and Cowell 1981), it appears that a considerable amount of price variation may not be accounted for by the application of the objective classification variables of sex, age, weight and fat depth. This is further supported by a number of surveys that have been conducted with retail butchers (Wilson and Wissemann 1981; Western Australian Department of Agriculture 1981; A.K. Collard, S. Anderson and J. Gilbert, Victorian Department of Agriculture, personal communication, March 1981).

Bouton, Ford, Harris, Shorthose, Ratcliff and Morgan (1978) suggested that variation in age–tenderness relationships partially depends on the age–weight range of the animals. Preston and Willis (1970) suggested that joint relationships could also exist between age, weight and fatness, with fatness and weight generally increasing with age. These joint relationships were also examined. Hence, previous research suggests that, for the domestic market, characteristics other than age, weight, sex and fat depth appear to influence buying decisions and, hence, would be expected to be important determinants of price.

The Model

On the basis of the research reviewed above, the following model was developed in order to examine carcass auction price variation:

$$(1)\quad P = f(S, A, D_j, W_k, F_k, MC_m, FC_m, TR_m, SO_k, SH_j, MT_k, FT_k, RE, L, FD_j, GF, M, B_m, BR)$$

where P = price;
S = sex;
A = age;
D = day of sale;
W = weight;
F = fat depth;
MC = meat colour;
FC = fat colour;
TR = trim;
SO = sale order;
SH = shape;
MT = meat texture;
FT = fat texture;
RE = ribeye area;
L = length;
FD = fat distribution;
GF = grain feeding;
M = marbling;
B = buyer;
BR = bruising;
k = 1, 2, or 3;
j = 1, 2, 3, or 4; and
m = 1, 2, 3, 4, or 5.

A detailed specification of each variable and the subscripts included in the model is given in the Appendix.

To determine whether or not the above characteristics were important explanators of prices paid, an F test was used. One characteristic was removed from the full model (equation (1)) at a time. An F test which compared the results of the new model and the full model was then carried out, in order to determine whether or not the omitted characteristic was significant. This procedure was repeated for each characteristic.

Thus the hypotheses to be tested can be generalised in the following manner:

$$(2)\quad H_o : B_j = 0$$

where j denotes the characteristic B_j (the coefficient in the full model associated with that characteristic). If there are n variables associated with characteristic j, then the null hypothesis is:

$$(3)\quad H_o : B_{1j} = B_{2j} = \ldots = B_{nj} = 0$$

In all, 19 hypotheses were advanced for testing.

Data

The data used in this study were collected from six auctions held over four days at two carcass auction centres during the week ended 5 June 1981. These two auction centres, which are within the Perth metropolitan area, generally operate on a daily basis with approximately 40 buyers in attendance. On average, the two auctions account for 1400 - 1600 carcasses a week. A total of 383 observations relating to full bodies, sides and quarters were collected over the trial period. However, because of constraints on resources, not all the carcass characteristics were recorded for the entire 383 observations. Carcasses with no observations for marbling were coded as not having that characteristic present. A complete set of data was available only for the quartered carcasses. Thus, the data set for the model was reduced to 183

observations. For some characteristics, such as shape, bruising and marbling, certain categories were poorly represented. A frequency distribution for the sample used in the analysis is presented for each carcass characteristic in Appendix B of Porter and Todd (1985).

Sex, age, weight and fat depth were recorded from the carcass classification ticket displayed on each carcass. Carcass characteristics of a subjective nature were measured using the Australian Beef Carcass Appraisal Method (AMLC 1980) as a guide. In order to gain a consistent assessment, meat colour and fat colour were categorised using the Western Australian Department of Agriculture (1981) photo code system.

Data Analysis

Most variables were included in the model as dummy categorical variables (see Appendix), while length (L) and ribeye area (RE) were included as continuous variables. The statistical technique used in order to examine the price–factor relationship was an analysis of covariance in accordance with the General Linear Model procedure available in the Statistical Analysis System (SAS) computer package (SAS Institute Inc. 1982).

For each categorical variable in the model (for example, fat depth), the variable associated with the reference category (for example, F_3) was removed. This overcame the problems of linear dependencies in the regression specification and allowed parameters of the model to be estimated. Estimates from the model are therefore relative to this reference category (see Appendix).

A number of specifications of equation (1) were examined in order to assess the impact of the interaction terms (such as age by weight, age by fat depth and weight by fat depth) prior to obtaining the full model. Weight and fat depth were included in the interaction terms as continuous variables only, in order to save degrees of freedom. The full specification, which included all variables discussed above and from which all hypotheses were tested, involved the weight by fat depth interaction only. This interaction was found to be significant in this preliminary testing phase.

Because prices were sequentially ordered over the sale period, autocorrelation was examined by the use of the Durbin–Watson test. However, no significant autocorrelation problem was encountered. Furthermore, application of the Goldfeld–Quandt test indicated no violation of the assumption regarding homoscedasticity. The extent of correlation between variables was examined using Spearman's rank correlation procedure (Conover 1971, p.245). The multicollinearity problem is discussed in the next section.

On the basis of the $\bar{R}^2$ criterion, the explanatory power of the full model was considered quite acceptable. The factors included in the model accounted for 78 per cent of the price variation within the carcass auction sales over the period studied. This result compares favourably with those obtained by Hall (1981) and Todd and Cowell (1981). Simpler models were also investigated because of the cumbersome nature of the full model.

Results and Discussion

The results of hypothesis testing are provided in Table 1. For the weight and fat depth variables, which appeared in the interaction term, testing for the significance of each of these factors was performed with the interaction terms also removed.

In the full model, age, meat colour, fat colour, day of sale, trim and whether or not a beast had been grain fed were found to be highly significant explanators of carcass prices. Length, sex, sale order and fat depth were found to be significant at the 5 per cent level. Fat texture and the weight by fat depth interaction term were significant at the 10 per cent level. In the full model, other factors, such as meat texture, shape, fat distribution, ribeye area, buyer, bruising, and marbling were found not to be significant explanators of carcass prices. However, some factors such as bruising and marbling were poorly represented in the sample.

From previous research (Hogan and Todd 1979) it can be seen that a 'time factor' can be an important explanator of price variation. The day of sale and sale order variables were included in the model to take account of price variation related to time. However, only those factors which could be incorporated into a carcass classification system are discussed here and these time-related variables are excluded from further discussion.

TABLE 1

Significance of Carcass Characteristics

Characteristic	*F* value	Level of significance
Day of sale	10.71	***
Sex	6.17	**
Age	8.43	***
Fat depth	3.90	**
Weight	0.17	
Weight × fat depth	2.84	*
Meat colour	13.01	***
Fat colour	8.20	***
Grain feeding	21.28	***
Trim	7.23	***
Length	5.04	**
Sale order	3.06	**
Fat texture	2.71	*
Shape	1.69	
Meat texture	2.20	
Fat distribution	1.38	
Marbling	0.04	
Buyer	1.14	
Bruising	0.02	
Ribeye area	0.05	

*** Significant at the 1 per cent level.
** Significant at the 5 per cent level.
* Significant at the 10 per cent level.

Intermediate models

The full model (equation (1)) has a large number of variables, some of which are subjective and some of which are not significant. Consequently, models were examined which fell between the current classification scheme and the full model in terms of the number of factors included. Factors with the highest remaining significance were added sequentially to the classification model to produce intermediate models.

The current classification scheme model was found to explain 38 per cent ($\bar{R}^2 = 0.3823$) of the variation in carcass prices. When meat colour and fat colour were added, 52 per cent of the variation was explained. With the addition of grain feeding, length and trim to form the final model, 75 per cent was explained. The extra seven variables in the full model added only a further 3 per cent to the explanation of price variation. In the final model, variables were objectively measurable and their influence on price is intuitively acceptable. Only factors which were significant at the 5 per cent level in the full model were included, with the exception of the weight by fat depth interaction term which was significant at the 10 per cent level and was specifically retained because of a priori knowledge.

Spearman's rank correlation procedure was used to examine correlation between the variables. Weight, fat depth, meat colour, fat colour and age were found to be strongly correlated. Previous research has shown that these characteristics are important factors in determining price. In this study, all the variables except weight were found to be significant in explaining price. Buyers take into account several different characteristics when determining price. The influence on price of one characteristic (for example weight) may be overshadowed by a number of other characteristics.

Final model

Parameter estimates for the final model are set out in Table 2. The sample's average price was 152.6c/kg. As mentioned above, coefficient estimates for categorical variables are interpreted in relation to the reference category (for example, for fat colour 5, 'dark yellow', a discount of 5.7 c/kg relating to fat colour 4 was estimated). These results give an indication of the direction of the effects but should be used with caution because of the constraints of sample size, period and location.

Sex was found to be a significant explanator of carcass prices. Buyers discounted steer carcasses by 6.1c/kg in comparison with heifer carcasses. Although the direction of the sex coefficient is inconsistent with previous research, this may still be a plausible result for the state and/or period in which the analyses were undertaken. Further analyses over a longer period and for different states may be necessary to resolve these differences.

Weight was included in the model both as a categorical variable and as a weight by fat depth interaction term. Weight as a categorical variable was found to be not significant. As discussed, this may be attributable to problems of multicollinearity in the model. However, the weight by fat depth interaction term was found to be a significant

explanator of carcass prices at the 10 per cent level. A negative coefficient for the weight by fat depth interaction term implies that for a constant fat depth, increases in weight are associated with a decrease in price per kilogram. Similarly, for a constant weight, increases in fat depth are associated with a decrease in price per kilogram.

TABLE 2
Final Model: Parameter Estimates

Variable	Estimate	Standard error
Intercept	200.2	19.11
Day 2	14.02	3.74
3	10.45	3.87
Sex	−6.10	1.98
Age	5.69	2.52
Fat depth 1	−8.18	3.43
2	1.47	2.46
Weight × fat depth	−0.0005	0.0012
Meat colour 2	4.11	2.43
4	−9.33	1.82
5	−13.59	3.60
Fat colour 1	14.38	3.81
2	14.71	3.01
3	14.02	2.91
5	−5.68	5.87
Grain feeding	15.80	2.57
Trim 2	−13.97	4.39
3	−13.28	3.02
4	−13.29	2.43
5	−3.97	9.47
Length	−0.48	0.12
Sale order 1	3.35	2.28
2	−2.33	2.08
$\bar{R}^2 = 0.7557$; $DW = 1.61$; $n = 183$		

Conclusions

In an examination of the carcass characteristics influencing beef carcass prices at two Perth carcass auctions, factors found to be highly significant determinants of price were age, day of sale, meat colour, fat colour, grain feeding and trim. Sex, fat depth, length, sale order, weight and fat texture were also found to be significant explanators of carcass price variations.

These results support the suggestion that beef is a complex product, with a large number of factors influencing price. Approximately 78 per cent of the price variation was accounted for by the measured factors. In terms of the factors that underlie 'carcass classification', as examined in Australia over recent years, the factors of age, weight, sex and fat depth were found to be significant. However, five other factors, which are not part of the 'carcass classification trial', were found to be significant. This suggests that it could be beneficial to include such factors in a classification system. Such an inclusion, however, would necessitate objective assessment of the characteristics. The factors are meat colour, fat colour, trim, length and whether or not animals have been grain fed.

However, it should be noted that these conclusions are based on a relatively small number of carcasses.

The results support the demand for improved reporting of both carcass attributes and prices at carcass auctions and at the abattoir. In terms of the export grades, which have recently been reviewed, a number of optional characteristics are available (Miller and Core 1982). Although this study involved carcasses for the domestic market, the conclusions may be applicable to some export markets if domestic and export buyers require similar carcass characteristics. Meat colour, fat colour, trim, grain feeding and length are the optional factors suggested by this study. Although the subjective factors may be difficult to monitor, visual aids may help overcome the measurement problem and thus they could be considered as options.

APPENDIX

Specification of Variables and Subscripts Used in the Model

P = Price in c/kg dressed carcass weight.

S = Dummy variable for sex, where $S = 0$ for heifer and $S = 1$ for steer.

A = Dummy variable for age, where $A = 1$ if < 2 teeth and $A = 0$ if $\geqslant 2$ teeth.

W_k = Categorical variable for cold carcass weight in kg.

W_1 = 1 if weight $\leqslant$ 100 kg, 0 if weight $>$ 100 kg.

W_2 = 1 if 101 kg $\leqslant$ weight $\leqslant$ 200 kg, otherwise 0.

W_3 = 1 if weight $\geqslant$ 201 kg, 0 if weight $<$ 201 kg (reference category).

F_k = Categorical variable for fat depth, cold carcass measurement (mm) at the 12th–13th rib interface.

F_1 = 1 if fat depth $\leqslant$ 2 mm, 0 if fat depth $>$ 2 mm.

F_2 = 1 if 3 mm $\leqslant$ fat depth $\leqslant$ 8 mm, otherwise 0.

F_3 = 1 if fat depth $\geqslant$ 9 mm, 0 if fat depth $<$ 9 mm (reference category).

MC_m = Categorical variable for meat colour. Range from light pink (code 1) to dark red (code 5) (Western Australian Department of Agriculture photo codes); where $MC_m = 1$ if meat colour is code m, otherwise 0 (reference category MC_3).

FC_m = Categorical variable for fat colour. Range from white (code 1) to dark yellow (code 5) (Western Australian Department of Agriculture photo codes); where $FC_m = 1$ if fat colour is code m, otherwise 0 (reference category FC_4).

SO_k = Categorical variable for time of sale (sale order) in terms of hook numbers within the sale, the sale being split into three equal periods; where $SO_k = 1$ if sale order = k, otherwise 0 (reference category $SO_3 = 0$).

D_j = Categorical variable for day of sale; where $D_j = 1$ if day of sale is day j, otherwise 0 (reference category D_4).

RE = Ribeye area (sq cm).

L = Length of carcass (cm).

SH_j = Categorical variable for butt profile. Range from poor muscle development (code 1) with distinct concave profile of leg and eye muscle to excellent muscle development (code 4) with super convex profile of leg and eye muscle (based on Australian Beef Carcass Appraisal Method; AMLC 1980). $SH_j = 1$ if code equals j, otherwise 0 (reference category SH_2).

FD_j = Categorical variable for fat distribution. Range from (code 1) uneven distribution to (code 4) even distribution (Western Australian Department of Agriculture codes). $FD_j = 1$ if code equals j, otherwise 0 (reference category FD_3).

MT_k = Dummy variable for meat texture. Range from (code 1) fine texture to (code 3) coarse texture (Western Australian Department of Agriculture codes). $MT_k = 1$ if code equals k, otherwise 0 (reference category MT_2).

FT_k = Dummy variables for fat texture. Range from (code 1) hard texture to (code 3) soft texture (Western Australian Department of Agriculture codes). $FT_k = 1$ if code equals k, otherwise 0 (reference category FT_1).

TR_m = Categorical variable for trim. Trim code = 1 if all in, tail on; trim code = 2 if all in, tail off; trim code = 3 if channel fat, kidney knob out and tail on; trim code = 4 if kidney knob out, tail off; trim code = 5 if tail off, kidney knob and channel fat out; where $TR_m = 1$ if code equals m, otherwise 0 (reference category TR_1).

GF = Dummy variable for a grain-fed carcass, where $GF = 1$ if the animal had been grain-fed, $GF = 0$ if not grain-fed or not recorded.

M = Dummy variable for marbling, where $M = 1$ if marbling is present, $M = 0$ if no traces of marbling or not recorded.

BR = Dummy variable for bruising, where $BR = 1$ if bruising occurs, $BR = 0$ if no bruising.

B_m = Categorical variable for buyer. Purchases of four individual buyers were recorded. $B_m = 1$ if code equals m, otherwise 0.

References

Australian Meat Board (1972), *Summary of Progress and Decisions of the Australian Meat Board's Committee on Beef Grading/Classification*, Sydney.

Australian Meat and Live-stock Corporation (1980), Australian beef carcass appraisal method, Sydney (mimeograph).

BAE (1981), *Livestock and Meat Marketing in Australia: An Economic Evaluation*, Industry Monograph No. 1, AGPS, Canberra.

Biggs, A. P. (1975), 'Beef carcass classification: current research and implications for marketing', *Quarterly Review of Agricultural Economics* 28(2), 67–79.

Bouton, P. E., Ford, A. L., Harris, P. V., Shorthose, W. R., Ratcliff, D. and Morgan, J. H. L. (1978), 'Influence of animal age on the tenderness of beef muscle differences', *Meat Science* (2), 301–11.

Buccola, S. T. (1980), 'An approach to the analysis of feeder cattle price differentials', *American Journal of Agricultural Economics* 62(3), 574–80.

Conover, W. J. (1971), *Practical Non-Parametric Statistics*, John Wiley, New York.

Fielder, L. L. and Martinez, A. (1974), *Weight Price Relationships for Calves, Steers and Heifers Marketed through Louisiana Auction*, Department of Agricultural Economics Research Report, Louisiana State University, Baton Rouge.

Hall, W. J. A. (1981), An analysis of cattle prices at auction and at weight and grade. Master of Agricultural Science thesis, University of Queensland.

—— (1984), Potential developments in the marketing of slaughter cattle. Paper presented to the Regional Beef Cattle Review and Outlook Conference, Albury, 31 August.

Hogan, J. C. and Todd, M. C. (1979), 'Empirical tests of spatial and structural effects on cattle auction prices', *Australian Journal of Agricultural Economics* 23(3), 176–90.

Keane, M. J. and Riordan, E. B. (1973), 'Product quality communication through price in the Irish cattle/beef industry' *Irish Journal of Agricultural Economics and Rural Sociology* 4(1), 1–23.

Miller, G. L. and Core, P. (1982), 'Proposed new single inspection services: framework for development', *Report of the Royal Commission into the Australian Meat Industry*, AGPS, Canberra.

Porter, D. and Todd, M. (1985), The effect of carcass quality on beef carcass auction prices. Paper presented to the 29th Annual Conference of the Australian Agricultural Economics Society, Armidale, 12–14 February.

Preston, T. R. and Willis, M. B. (1970), *Intensive Beef Production*, Pergamon Press, Oxford.

Statistical Analysis System (SAS) Institute Inc. (1982), *SAS User's Guide: Statistics*, Cary, North Carolina.

Todd, M. C. and Cowell, M. D. (1981), 'Within-sale price variation at cattle and carcass auctions', *Australian Journal of Agricultural Economics* 25(1), 30–47.

Western Australian Department of Agriculture (1981), *An Evaluation of Beef Carcass Classification in Western Australia*, National Carcass Classification Supervisory Committee, Report to the Standing Committee on Agriculture on Manual Beef Carcass Classification in Australia, Annex 4, Appendix 4, Perth.

Wilson, T. P. and Wissemann, A. F. (1981), 'A note on the attitudes of retailers to beef carcass classification', *Review of Marketing and Agricultural Economics* 49(1), 47–60.

Wittenburg, J. (1977), *A Regional Analysis of Beef-Cattle Prices*, Miscellaneous Study No. 63, Department of Agricultural Economics and Management, University of Reading.