Does Muscle Matter? An Economic Evaluation of Live Cattle Characteristics

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The Queensland Livestock Market Reporting Service (QLMRS) was established in 1980 by the Livestock and Meat Authority of Queensland. Weekly reports on the major live cattle auctions in Queensland indicate the prices of different types of cattle, categorised by their age, sex, weight, fat score and type of feed. Previous research has suggested that differences in these characteristics account for only some of the price variation observed at cattle auctions. This paper investigates other characteristics not included in the QLMRS market reports which may be important in determining the price of cattle. Data on the standard QLMRS characteristics and on other potentially important characteristics have been collected by the authors for a large number of lots of live cattle sold at two different auction sites in Queensland. This paper analyses the contribution both of characteristics regularly reported by the QMLRS and of other characteristics not reported by the QLMRS to explaining the variation in prices observed at these auctions. Hedonic price models are estimated which provide estimates of the premiums and discounts associated with different levels of the characteristics for which data were collected. The paper highlights the limitations of current market reports and indicates that the inclusion of muscle score may add considerably to the information content of these reports. More generally, the analysis suggests that liveweight auctions may not represent an efficient price discovery mechanism for cattle.

1. Introduction

Live cattle auctions are central to the price setting mechanism for live cattle in Australia. The importance of the auction in the generation of prices in the beef cattle market was explicitly recognised with the introduction of independent market reporting of auctions by the various livestock authorities throughout Australia in the late 1970s and early 1980s. The role of these Livestock Market Reporting Services (LMRS) is to disseminate information about the prices established for livestock at the major auction centres in each State. The effectiveness of the LMRS in this role, as indicated by the information content of their market reports, can be assessed by examining how much of the variation in observed auction prices is explained by the characteristics included in the market reports. The market reports compiled by the Queensland LMRS (QLMRS) contain information about the average prices of lots of cattle sold, with the reports disaggregated on the basis of five characteristics: age, sex, weight, fat score and whether the animals had been grass or grain fed. An earlier examination of the information content of QLMRS market reports which was based on individual lot data, revealed that, while the explanatory power of the QLMRS characteristics was reasonably strong for some types of cattle and some saleyards, a significant proportion of price variation was left unexplained (Williams *et al.* 1989).

The most likely explanation for this result was that there were unreported characteristics which were of importance to buyers and which, therefore, contributed to explaining the price of any particular lot of cattle. However, a second possibility was that the market was not operating efficiently and that there was considerable inherent random price variability in the auction system. Two other potential reasons for the unexplained proportion of price variation were misspecification of the functional form used in the analysis and measurement error.

This paper investigates whether information on additional potentially important price-determining characteristics collected at four Queensland cattle auctions in Winter 1990 adds significantly to the proportion of price variation explained. In particular, the significance of these additional characteristics in explaining price variation is tested to determine which, if any, of these characteristics may be potentially useful additions to market reports. In addition, estimates are obtained of the premiums

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and discounts associated with changes in the bundle of characteristics possessed by a specific lot of cattle compared with the bundle of characteristics held by a reference lot. The analysis is undertaken with careful attention being given to the potential statistical problems not only with misspecification and measurement error (for the reasons just outlined) but also with multicollinearity in the explanatory variables.

2. Potentially Important Characteristics

Previous empirical studies have examined the effect of different characteristics on the price of cattle and beef carcasses sold in Australia (Hogan and Todd 1979, Park 1979, Hall 1981, Todd and Cowell 1981, Porter and Todd 1985 and Williams *et al.* 1989). The characteristics examined in these studies included those used in the QLMRS reports (age, sex, weight, fat score and feed type) but also included some other characteristics: breed, district of origin, lot size, presence of horns, and the position of the lot within the sale. These characteristics were chosen on *a priori* grounds and tested empirically. A summary of the results of these studies is given in Table 1.

The results of the different studies are often inconsistent. For example, weight was not found to be significant by Porter and Todd (1985), but was found significant by Todd and Cowell (1981) and Williams *et al.* (1989). This may be explained by the different age/weight of animals investigated. Alternatively, the inconsistencies may be the result of the difference in techniques used to investigate the significance of these characteristics, as discussed further below.

However, rather than uncritically adopting the above group of characteristics as being the relevant characteristics for inclusion in the current analysis, the choice of relevant characteristics was investigated, using a 'first principles' approach, by examining closely both characteristics which buyers may regard as important and some other characteristics which may influence the price paid by buyers.

2.1 Characteristics Evaluated by Buyers[1]

On the basis of informal questioning of cattle buyers, the three most important criteria they consider when assessing the value of the cattle on offer at an auction are: the requirements set by end-users[2] (as spelt out by (usually minimum) specifications 'based on certain characteristics[3]); the perceived quality of the meat which can be obtained from the cattle; and the perceived yield of meat from each lot. Buyers will appraise the characteristics of the cattle in each lot in relation to these three criteria. A particular characteristic may often be relevant to each set of criteria, although the importance will vary between them and may produce conflicting results. For instance, fat depth may have a positive influence on carcass quality but a negative influence on carcass yield. The importance and effect of the fat depth characteristic on the final price is thus uncertain. For export-type cattle the most important criterion which needs to be satisfied would appear to be end-user specified minimum requirements, whereas cattle for domestic markets are likely to be assessed first on quality considerations. The market, therefore, is roughly segregated into cattle suitable for export and cattle suitable for the domestic trade. Older and/or heavier cattle (cows, heavy steers and bulls) are in demand principally for export, while younger stock (vealers, yearlings, light steers and heifers) dominate the domestic market. The likely importance of characteristics with regard to the three criteria is summarised in Table 2.

2.1.1 Characteristics used in end-user specifications

Characteristics for which end-users commonly specify particular categories or scores are age/sex,

[1]Buyers at the auctions studied are typically representatives of large meat-processing companies,

[2]End-users here are the wholesalers and retailers who buy from the meat processors, rather than the final consumer of the meat. In the case of export cattle, the end-users are importers in the country to which the buyers are exporting the meat.

[3]Requirements of some end-users are reasonably specific. For example, end-users (importers) requiring "Jap Ox" will only accept heavy steers less than four years old with fat score 3 or 4 (fat depth between 7 and 22 millimetres), and a butt profile of A, B or C.

Table 1: The Relationships Between Various Characteristics for Live Cattle and Auction Prices Observed by Previous Researchers

Characteristic:	Relationship found:	
Age	-ve	Hall Todd and Cowell
	none	Park Porter and Todd
Sex	premium for steers	Todd and Cowell
Weight	-ve	Park Todd and Cowell
	none	Hall
	+ve or -ve depending on sex/age/weight groups	Williams et *al.*
Fat depth/score	+ve	Park Todd and Cowell
	non-linear	Porter and Todd Williams *et al.*
Type of feed	premium for grainfed	Porter and Todd Williams *et al.*
Breed	premium for certain breeds	Todd and Cowell
Area of origin	premium for certain regions	Todd and Cowell Hall
Number of head in a lot	+ve	Hogan and Todd Todd and Cowell Williams *et al.* (for some age/sex groups only)
Presence of horns	none	Todd and Cowell
Order of sale	price rise at end of sale	Todd and Cowell

weight, fat score, muscle score (or butt profile) and feed type (see Table 2). Export orders, principally from the United States and Japan, use broad categories or ranges to specify the required characteristics. When estimating these characteristics, buyers will seek to classify the cattle in each lot according to these broad categories rather than assessing these characteristics for each lot on a continuous scale. That is, lots are appraised as falling into certain categories with respect to each of the characteristics. Buyers do not need to estimate precisely how each lot should be scored according to each characteristic.

On the other hand, domestic orders tend not to make such general categorical distinctions. There are two main reasons for this marked difference between these two market segments. The first is that the domestic market absorbs a wide variety of cattle. The second is that purchases for the domestic market tend to be based on quality and quantity objectives rather than on pre-determined specific end-user requirements.

Table 2: A Subjective Rating of Cattle Characteristics with Regard to Classification, Quality, and Dressing Percentage and Yield

Characteristic	Importance of characteristic with regard to:		
	Classification	Quality	Dressing percentage and yield
Age/sex	**	*	**
Weight	**		
Fat score	**	**	**
Feed Type	**	**	**
Muscle score	**	**	**
Breed		**	*
Area of origin		*	*
Bruising	*	**	*

** indicates very imporant characteristic
* indicates important characteristic

2.1.2 Characteristics affecting quality

Meat quality is obviously important to buyers. As already indicated, it is the principal determinant of meat price in the domestic market. Certain determinants of meat quality such as fat colour, meat colour and marbling (which cannot be observed directly at live cattle auctions) may also be specified as requirements for certain export markets. Characteristics that buyers at live cattle auctions could consider important in relation to quality include fat score, muscle score (as an indicator of weight-for-age), feed type, breed, feed availability (as indicated by district of origin and distance travelled) and the potential for bruising (as indicated by temperament, the presence of horns, and the distance travelled). (See Table 2.)

A reasonable amount of fat, as indicated by fat score, is generally seen as a desirable characteristic. Too much fat is, however, seen as undesirable, representing wasted kilograms of fat which must be removed prior to sale to the retail sector. The relationship between price and fat score is not expected to be linear, rather price is expected to increase as fat score approaches some optimal level and thereafter the relationship between price and fat is expected to be negative. (See Table 1 for previous relationships found between fat depth (or its categorical measure, fat score) and price.)

The relationship between the characteristics grain feeding and muscling and price is expected to be a positive one. The breed of cattle may be significant if buyers believe some breeds produce meat which is better marbled or has better fat colour than others. There should be a negative relationship between price and the presence of horns and poor temperament, because these characteristics increase the risk of bruising. The distance travelled, as indicated by the district of origin, may have both negative and positive influences on price. Long distances travelled mean the cattle have been exposed to the risk of bruising and have been off feed, but offsetting this is the possibility that they may have come from an area of high quality feed as compared to local cattle. (Again, see Table 1 for previous findings.)

2.1.3 Characteristics affecting dressing percentage and yield

The physical yield of meat from a lot determines the ultimate output of the processor, and so characteristics influencing yield are important. In general, cattle that have grown quickly and have a high proportion of meat compared to bone, fat and other carcass components will yield well. Characteristics that processors consider important in this regard are age, sex, fat depth, muscle score, breed type, the type of feeding (including grain) and the likelihood of bruising. (See Table 2.) Cattle that are aged or very fat tend to yield poorly. A positive relationship will probably exist between yield and muscle score, grain feeding and high quality feed. Males are generally preferred because of the risk of pregnancy and the consequent low meat yield associated with pregnant females. There may be a premium for heifers out of feed lots because these females are effectively guaranteed not to be pregnant. Again, breed type could be significant if buyers hold strong perceptions about the yield characteristics of certain breeds. There is likely to be a negative relationship between yield and the presence of excess fat and the likelihood of bruising, both factors that reduce yield.

2.2 Other Potentially Important Characteristics of the Lot

There are a number of other potentially important characteristics which may influence how buyers evaluate each lot of live cattle offered for sale. Two of these factors relate to the fact that cattle are sold in lots at Queensland liveweight auctions with sale lots consisting of from one to twenty head. Prices paid are for the lot and therefore characteristics relating to the formation of the lot, such as the degree of heterogeneity in the lot as well as the number in the lot may be important. Another potentially important factor is the position of the lot in the auction.

2.2.1 Heterogeneity of the cattle within a lot

Prices for each lot vary due to differences in the average characteristics exhibited by each lot. However, prices may also differ due to the different degrees of heterogeneity between lots. The relatively large cost per head of selling lots consisting of only a small number of head encourages vendors to build larger lots. Consequently the heterogeneity within any particular lot (due to differences between individual animals) may be as great or greater than the differences between lots. Given two lots with the same average characteristics, one could expect buyers to pay more for the lot with the least variation from beast to beast within the lot. Thus, the degree of uniformity of cattle within a lot may contribute to the explanation of price variation between lots, with premiums being paid for the more uniform lots.

2.2.2 Number of head in a lot

The number of head in a lot may itself be an important variable in explaining price variation. Heterogeneity will tend to increase with the number of head of cattle in a lot. On the other hand, post-auction handling costs per head tend to vary inversely with the number in the lot. For example, one animal from each lot must be tested post-sale if the cattle are destined for human consumption. This and other per lot costs may lead to some discounting of the price for small lots. This may be offset by the price premium a small lot may attract because it is more homogeneous. Such a positive relationship between price and lot size was found by Hogan and Todd (1979), Todd and Cowell (1981) and Williams *et al.* (1989). (See Table 1.)

2.2.3 Position of the lot in the order of sale[4]

Much theoretical and experimental work has been carried out both in Australia (Jarratt 1987, Vlastuin 1988, and Whan and Richardson 1969) and over-

[4]The rationale for including this variable in the present analysis is to identify all possible sources of price variation. However, as the standard practice at Queensland auctions is to draw for lot position, it is recognised that this information, about the relative price advantage of different lot positions, is redundant for decision-making purposes, and thus for inclusion in market reports.

seas (Sosnick 1963, Smith 1965, and Buccola 1982) on the effect of the order of sale on auction prices. The empirical evidence is mixed. Of the Australian authors, Jarratt (1987) found that position in the sale was an important determinant of price, while Vlastuin (1988) found no consistent effect. The relative strength of supply and demand may determine not only whether this variable is important but also its likely sign. Whan and Richardson's (1969) analysis implied that, in a thin market with few buyers, a downward trend can be expected, with average prices falling as commitments are met and buyers leave the auction. With many buyers and few vendors, the reverse may be expected.

3. Data

Data for this study were collected by the authors at auctions at Toowoomba and Rockhampton during Winter 1990. Prices paid at these auctions for 1518 lots of cattle were recorded (in cents per kilogram liveweight) along with observations of a set of the characteristics possessed by each lot. Characteristics recorded for each lot, chosen with reference to the above considerations, were: age/sex, average weight, average fat score, average muscle score, breed type, district of origin, the presence or absence of horns, uniformity of the lot, number of head in the lot, the position of the lot in the order of the sale and the type of feed. In the case of Rockhampton, additional information was collected on the auctioneer responsible for the sale of each lot.[5]

Actual liveweights were obtained for each lot by observing the post-sale weighing of each lot. However, the analysis is carried out using weight as a categorical variable, using the weight ranges used in the QLMRS reports. Buyers estimate weights prior to bidding at auction, so some discrepancies could exist between their subjective assessments and the actual weights, resulting in potential measurement error. This difference, and thus any measurement error, is minimised by the use of categorical weight variables. More importantly, because of end-user requirements, particularly in the export market, buyers tend to assess lots into appropriate weight ranges instead of estimating weight to the nearest kilogram.

Fat score, muscle score and uniformity of lot were estimated by the authors. It is possible that their estimates differed from those of the buyers (and those of the market reporters), but because wide categories were used, it is anticipated that any differences would be minimal.[6] Muscle score, as with the weight ranges and fat scores, is based on the AUS-MEAT specifications. However, many export cattle (at least in 1990) were graded on butt profile, which is effectively a combination of fat and muscle scores. It is possible, therefore, that for some export-type cattle, the muscle score reported will not fully reflect the buyers' criteria. Interaction terms of weight*fat, weight*muscle and fat*muscle were included in the analysis to allow for this possible weakness.

Breed type was also assessed by the authors. The area of origin was split into four broad groups, to reflect both the distance travelled and the quality of feed on which the cattle had been fattened. The collection of data on number in each lot, the position of the lot in the sale, the presence or absence of horns, and feed-type was straight forward. Full details of the data collection process are given in a Data Appendix.

4. Methodology

Live cattle are a heterogeneous commodity where the unique bundle of characteristics exhibited by each lot differentiate them from other lots of cattle offered for sale. An appropriate framework for analysing the contributions of these characteristics to auction prices is hedonic price analysis. This branch of demand/price theory is generally credited to Lancaster (1971), although there were earlier attempts to link product characteristics with price, for example, in Waugh (1928). Hedonic pricing is based on the concept that goods and services are composed of attributes and that the value of those attributes contributes to the price of the good. In many cases it is impossible to value

[5] At the Toowoomba auctions, each sale is conducted by only one agent. Data on the auctioneer were thus redundant.

[6] Analysis by Naughtin (1980) and Naughtin and Holland (1982) found that errors are not likely to be of such a magnitude to take the estimate out of the appropriate range. Further research on the accuracy of market reporter estimation is planned.

directly the individual attributes or characteristics of goods. However, because the presence of these attributes contributes to the price of the good or service, the value of the attribute is implicitly contained, or reflected in the total price. If a number of sale prices for a heterogeneous good are collected, multiple regression techniques can be used to estimate the implicit values that buyers place on each characteristic or attribute or, as is the case here, to estimate the premiums and discounts associated with a change in the bundle of characteristics compared with some standard bundle. Individual lot data are analysed to explain variations in prices by variations in the average characteristics of the cattle in the lot in question. Multiple regression techniques are used to estimate a hedonic price model.

4.1 The Hedonic Price Model

A hedonic price model is a reduced form equation, which shows how the endogenous variable, price, is determined by exogenous variables. A reduced form equation does not directly describe the behaviour of economic agents but instead reports the results of their behaviour on price. No specific functional form is suggested by theory and this is, therefore, a matter for empirical determination (Williams 1989).[7]

For the same reasons discussed by Williams *et al.* (1989), the analysis in this study is carried out at a disaggregate level by estimating a different hedonic price function for each of four age/sex groupings (yearlings, heifers, cows and steers) at Rockhampton and Toowoomba.[8]

The general form of the estimated model is:

$$P_i = P_o + \Sigma X_{ij} p_j + \epsilon_i$$

where P_i is the price of the *i*th heterogeneous lot;
P_o is the price of the reference lot of cattle;
X_{ij} is the average quantity of the *j*th characteristic provided by the *i*th lot (measured relative to the base quantity held by the reference lot);
p_j is the premium/discount associated with a unit change in the amount of characteristic provided by the *i*th lot compared with the reference lot; and
ϵ_i is the error term.

The regressors included in the hedonic price model are the characteristics on which data were collected, as discussed above, plus three groups of interaction terms: weight*fat, weight*muscle, and fat*muscle.

4.2 Multicollinearity Problems

Two basic techniques have been used to analyse the importance of different characteristics on the price of cattle. The first technique, used by Porter and Todd (1985), was to estimate the full hedonic price equation including all potentially important characteristics of the cattle sold for which they had data, and then test, using F-tests, for the individual significance of each characteristic on price. This was done by systematically estimating a series of equations in which each one of these characteristics was omitted from the full equation. The second approach, used by Todd and Cowell (1981), was an analysis of covariance approach, using multiple regression to determine the significance of different characteristics.

However, neither of these techniques are valid if the data to be analysed are beset by multicollinearity in the explanatory variables. In the use of the F-test, if two characteristics are strongly correlated, the omission of either one of these from the estimated equation may appear to have an insignificant effect on the explanatory power of the regression function. So both characteristics can be found to be insignificant using this approach, even though both may be individually significant in the absence of the other. In the Todd and Cowell (1981) study, the use of multiple regression techniques in the presence of multicollinearity has associated with it the classic problems of inflated variances of the af-

[7]The functional form used for this analysis is linear in all the variables. RESET tests were used along with various heteroskedasticity tests to test for specification error. See Tables 4 and 5.

[8]Although the two Rockhampton sales were separated by a week, Chow tests showed that the underlying relationship was the same, after an allowance was made for a shift in the intercept term, reflecting a lowering of the underlying average price over the period.

fected parameter estimates and the consequent false acceptance of the null hypothesis of no relationship.

The contradicting results with regard to the importance of weight and age as a determinant of cattle prices in Todd and Cowell (1981), and Porter and Todd (1985) may be explained by the presence of multicollinearity in their data sets. Porter and Todd (1985) admit to strong correlations in their data set. They found that weight was not a significant determinant of price but that the weight*fat interaction was significant. This again may be a result caused by a high correlation between the weight and weight*fat variables.

Severe problems of multicollinearity were experienced in the analysis of the current data set. Its existence in all sex/age data groupings indicate that this is a widespread problem. As noted above this may cast some doubt on the validity of previous research in this area.

The inflated variances caused by multicollinearity affect only those variables affected by the dependencies within the set of variables. The initial step, therefore, is to uncover the extent of the multicollinearity within the data set and to discover what form the dependencies take. This will reveal which of the regressors are likely to have coefficient estimates which are adversely affected by the collinearities. It will also allow the identification of coefficient estimates which are relatively isolated from the collinearity problems and thus likely to be trustworthy in spite of the ill-conditioned data set.

The simple correlation coefficient between pairs of the explanatory variables is inadequate as a measure of the potential problem variables. Often in multiple regression analysis, relationships exist between groups rather than pairs of these variables. A more thorough approach is to examine the eigenvalues and condition indices (CIs) of the scaled matrix of the explanatory variables, **X'X**.[9] The *i*th CI is defined to be

$$\sqrt{\frac{\lambda_1}{\lambda_i}}$$

where λ_1 is the largest eigenvalue, and

λ_i is the ith eigenvalue of the normalised **X'X**.

Belsley *et al.* (1980, pp.100-105) show that moderate to strong dependencies are associated with CIs between 30 and 100. Corresponding to each high CI is a strong dependency in the matrix. Severe multicollinearity is indicated by CIs greater than 100. This level of multicollinearity 'causes substantial variance inflation and great potential harm to regression estimates' (Belsley *et al.* 1980, p.153).

If the existence of such multicollinearity is indicated by the CIs, the next step is to determine the nature and likely effect of the multicollinearity on the parameter estimates of the model. The form of the dependencies is indicated in the variance-decomposition proportions of the regression coefficients.[10]

For high CIs, the presence of high variance proportions for two or more coefficients indicates that a relationship may exist between those variables. Belsley *et al.* (1980) provide a simple rule of thumb: that estimates are considered to be degraded by multicollinearity when more than 50 per cent of the variance of two or more coefficients is associated with a single high CI.

Conducting these tests on the current data set revealed CIs in excess of 300, with associated high variance proportions for several coefficients. The problem variables were found to be the interaction terms and the weight, muscle and fat variables. Generally, these are the only variables involved in the collinearities. The coefficient estimates for the other characteristics can be regarded as 'clean', that is, unaffected by inflated variances and the related instability of the estimates.

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[9]The data matrix is scaled in such a way as to make each column of the data matrix have unit length. This is necessary to allow the use of the condition indices as indicators of dependencies within the data matrix.

[10]The variance of each regression coefficient can be split into a sum of components, each associated with one and only one eigenvalue. The variance-decomposition proportion (or variance proportion as it is referred to in the Shazam program [White *et al.* 1988]), is the proportion of the variance of the regression coefficient associated with the *j*th eigenvalue.

No satisfactory solution exists to 'cure' multicollinearity. The collection of more data may not solve the problem - especially if the relationship is intrinsic (or by way of nature) as it is in this case.[11] Data transformations are not always possible (and may not cure the underlying problem anyway). Principal components analysis and ridge regression are suggested as options in textbooks - and then not recommended! (See Judge *et al.* 1988, p.874.) An alternative is to estimate the model, removing some of the troublesome variables, but recognising at the same time that the coefficient estimates for the retained variables which formed part of the original collinearity problem are composite. The problem of the inflated variances is removed but the coefficient estimates can no longer be correctly interpreted as relating to individual variables but rather as the composite effects of included and omitted variables.

In the current analysis, the exclusion of the interaction terms removed all troublesome multicollinearity problems, with the CIs falling from unacceptably high values to, in most cases, below 20. For example, the removal of the muscle*weight and muscle*fat interactions reduced the maximum CI from 170 to 17, for heifers at Rockhampton.

4.3 Analytical Approach Adopted

The analysis has been conducted in a series of steps, the first four of which can be explained by reference to Table 3A. First, full hedonic price models were estimated for each sex/age cattle type at each auction site using data on all the characteristics observed and the three groups of interaction terms (model A). The coefficient of multiple determination (R^2) and the adjusted R^2 for these eight full models are presented in the first row of Table 3A.

The next step was to re-estimate these eight equations excluding the three groups of interaction terms due to the multicollinearity problems they created (see earlier discussion). These slightly simpler models (model B) were then compared, using F-tests, with model A to test whether the omission of the interaction terms resulted in a significantly different (i.e. worse) model. The level of significance of these tests are shown, along with R^2 and the adjusted R^2, in the second row of Table 3A.

The third step was to estimate eight new models (model C) by excluding all variables (and their interaction terms) representing characteristics not currently reported in the QLMRS reports. These models were then compared with model A to test whether the amount of price variation explained by model C was significantly different (less). (See the third row in Table 3A.)

Fourthly, the models including only the characteristics reported by the QLMRS without any interaction terms (model D) were estimated and compared with the full model. (See the last row in Table 3A.)

The next question addressed was the contribution of each of the characteristics to the explanatory power of model A. The contribution of the characteristics not currently reported by the QLMRS were of special interest. The results of these investigations are summarised in Table 4.

The F-test technique of Porter and Todd (1985) discussed above was used to test whether a characteristic or group of characteristics had a significant effect on price. The apparent non-significance of variables associated with the multicollinearity problem in the data (weight, fat, muscle and their interactions) should be interpreted with caution because of the inflating effect of multicollinearity upon the variances. No conclusion can be made about the statistical significance of these variables.

Finally, estimates of premiums and discounts associated with different levels of each characteristic compared with a base level for that characteristic in the reference lot were determined on the basis of model B (i.e. excluding interaction terms).[12]

These estimates (reported in Table 5) will be most reliable, therefore, for those variables unaffected by the multicollinearity. The potential for

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[11] The aggregation of the data for the two Rockhampton sales did, however, remove some problematical collinearity between sequence and the auctioneer dummy variables.

[12] The reference lot consists of animals in weight range 1, fat score 3, muscle score C, of non-specified breed, coming from the local area, without horns and grass-fed. For yearlings, the base is taken to be male.

Table 3A: A comparison of models

Model	Statistics	Cows		Yearlings	
		Rockhampton	Toowoomba	Rockhampton	Toowoomba
Model A Full model, including interactions	R^2 R^2 (adjusted)	0.4637 0.3542	0.7523 0.6870	0.5057 0.3126	0.6432 0.5889
Model B Full model, excluding interactions	R^2 R^2 (adjusted) Significance level of difference from Model A	0.4270 0.3403 N.S.	0.7268 0.6773 N.S.	0.4760 0.3108 N.S.	0.5699 0.5290 1%
Model C QLMRS model, including interactions	R^2 R^2 (adjusted) Significance level of difference from Model A	0.2408 0.2036 1%	0.6334 0.6069 1%	0.1387 0.0858 1%	0.4955 0.4737 1%
Model D QLMRS model, excluding interactions	R^2 R^2 (adjusted) Significance level of difference from Model A	0.2279 0.2008 1%	0.6244 0.6050 1%	0.1379 0.0929 1%	0.4700 0.4565 1%

Table 3A (continued)

Model	Statistics	Steers		Heifers	
		Rockhampton	Toowoomba	Rockhampton	Toowoomba
Model A Full model, including interactions	R^2 R^2 (adjusted)	0.7817 0.7481	0.7214 0.6741	0.6449 0.5011	0.7342 0.5911
Model B Full model, excluding interactions	R^2 R^2 (adjusted) Significance level of difference from Model A	0.7639 0.7313 1%	0.6805 0.6435 1%	0.5804 0.4558 5%	0.6472 0.5296 10%
Model C QLMRS model, including interactions	R^2 R^2 (adjusted) Significance level of difference from Model A	0.6629 0.6477 1%	0.4591 0.4357 1%	0.2185 0.1839 1%	0.5830 0.5430 N.S.
Model D QLMRS model, excluding interactions	R^2 R^2 (adjusted) Significance level of difference from Model A	0.6528 0.6415 1%	0.4544 0.4381 1%	0.2166 0.1892 1%	0.4763 0.4414 1%

misspecification error with the omission of the interaction terms is recognised. As indicated by the results in Tables 3 and 4, the groups of interaction terms are often significant in explaining price variation. However, the model without the interaction terms (model B) has been used to illustrate the potential magnitudes of price differences, for example, between cattle identical in every way except in muscle score. Inclusion of the interaction terms, with their related multicollinearity, makes the coefficients for weight, fat and muscle score difficult to interpret and little can be directly deduced about the magnitudes of price differences between muscle scores, for example.[13] The equations reported in Table 5 have coefficients which are 'sensible' and which can be unambiguously interpreted as the premium/discount associated with a unit change in the amount of the characteristic, as compared with the base level used for that characteristic.

Table 3B: The impact of muscle score

Model	Statistics	Cows		Yearlings	
		Rockhampton	Toowoomba	Rockhampton	Toowoomba
Model C plus muscle score	R^2	0.3267	0.6960	0.3183	0.6160
	R^2 (adjusted)	0.2644	0.6535	0.2291	0.5832
	Significance level of difference from Model C	1%	1%	1%	1%

Table 3B (continued)

Model	Statistics	Steers		Heifers	
		Rockhampton	Toowoomba	Rockhampton	Toowoomba
Model C plus muscle score	R^2	0.7118	0.6869	0.5241	0.6734
	R^2 (adjusted)	0.6873	0.6585	0.4600	0.5917
	Significance level of difference from Model C	1%	1%	1%	1%

While problems of measurement error were minimised through the use of categorical rather than the estimated continuous variables, as discussed in Section 3, potential problems of misspecification remain. Two types of misspecification tests were carried out, that is, the RESET test and the Durbin-Watson (DW) test. (See Tables 4 and 5.) The DW test is relevant here as the data are ordered in sequence of sale for each particular sex/age cattle type. While the Sequence variable is included to incorporate any specific order of sale effect, the DW test statistic can be used to check on any misspecification of the Sequence variable.

5. Results

As already indicated, there are three sets of statistical results: a comparison of the relative explanatory power of the various hedonic price models (Table 3A); an evaluation of the importance of the various individual characteristics (Tables 3A, 3B and 4); and estimates of premiums/discounts associated with different levels of the individual characteristics (Table 5). As with previous similar research, multicollinearity in the variables and model misspecification have been potential problems. The steps taken to address multicollinearity have already been explained (see section 4.2). However, the tests conducted in relation to model specification are considered below. Finally the relatively large proportion of 'noise' (or unexplained variation) in the observed prices is discussed.

5.1 Overall Explanatory Power of the Hedonic Price Models

Model A, incorporating all the characteristics for which data were collected and the three sets of interaction terms, explains between 51 per cent (Yearlings at Rockhampton) and 78 per cent (Steers at Rockhampton) of the price variation observed at the auctions studied (Table 3A). Excluding the troublesome interaction terms (model B) did not significantly reduce the explanatory power of the equations for Cows at either auction site nor for Yearlings at Rockhampton. However, model B was found to be statistically different (worse) relative to model A for the other five sectors, with the proportion of the price variation explained falling by up to 8 percentage points (Heifers at Toowoomba).[14]

Removing the variables representing the characteristics not currently reported by the QLMRS (model

[13] In addition, the work of Cropper, Deck and McConnell (1988) suggests that, when there is measurement error or variable misspecification as may be the case here, the simple linear hedonic price function outperforms more complex models incorporating interaction terms in terms of the accuracy of implicit prices.

[14] The heifer market at Toowoomba was, at the period of this study, dominated by the export market, particularly that of Korea. Specifications for the Korean market are precise, requiring a particular combination of weight, fat and muscle score. This may explain the importance of the interaction terms for this sector of the market.

Table 4: Tests of the significance of characteristics of live cattle in price determination using the full model (Model A)#

Excluded Variable(s)	Cows		Yearlings	
	Rockhampton	Toowoomba	Rockhampton	Toowoomba
Weight	0.17 [3]	1.12 [3]	0.11 [1]	1.57 [2]
Fat score	0.76 [4]	17.89 [5]***	0.31 [2]	10.20 [2]***
Weight·fat	0.27 [3]	0.99 [3]	0.02 [1]	1.47 [4]
(All weight, fat)	0.58 [10]	11.32 [11]***	0.33 [4]	9.20 [8]***
Muscle score	3.36 [3]**	3.51 [3]**	1.66 [3]	2.77 [2]*
Muscle·weight	2.51 [3]*	1.44 [4]	2.56 [3]**	3.69 [3]**
Muscle·fat	0.05 [3]	3.18 [2]**	0.83 [1]	1.11 [4]
(All muscle)	2.48 [9]***	2.62 [9]***	4.11 [7]***	7.12 [8]***
Breed	1.70 [6]***	1.38 [6]	1.03 [6]	0.54 [6]
Origin	1.70 [3]	3.26 [3]**	0.75 [3]	2.41 [3]*
Horns	3.47 [1]*	0.80 [1]	0.01 [1]	0.14 [1]
Uniformity	2.20 [1]	1.78 [1]	0.05 [1]	0.05 [1]
Number in lot	0.80 [1]	3.60 [1]*	1.24 [1]	7.84 [1]***
Sequence	2.39 [2]*	3.09 [2]**	0.08 [2]	0.54 [1]
Auctioneer	1.88 [6]	NR	1.84 [6]*	NR
Feed	NR	NR	0.38 [1]	2.19 [1]
Sex	NR	NR	3.57 [1]*	8.25 [1]***
Sale	21.65 [1]***	NR	3.38 [1]*	NR
RESET(2)	1.77	0.14	3.11*	3.63*
RESET(3)	1.67	1.08	2.62*	2.04
RESET(4)	1.12	0.81	1.79	1.37
DW	2.03	1.99	2.17	1.98
R^2 (R^2 adjusted)	0.464 (0.354)	0.752 (0.687)	0.506 (0.313)	0.643 (0.589)
Sample Size (number of lots)	237	164	122	243

Number in bracket [ ] indicates number of excluded variables
NR denotes that the variable was not relevant
*** significant at 1% level
** significant at 5% level
* significant at 10% level
# The figures reported are F-statistics, formed by excluding subgroups of variables from the full model including all relevant interaction terms.

C) reduced the explanatory power of seven of the eight equations to a marked degree (and these reductions were all statistically significant at the 1 per cent level). The exception was the model for Heifers at Toowoomba. The results for models C and D (rows 3 and 4 of Table 3A) demonstrate that only for Heifers at Toowoomba do the interaction terms of the QLMRS-reported characteristics (weight and fat) have any sizeable effect on the explanatory power of the model. For some of the other age/sex groups, excluding the interaction terms actually improved the adjusted R^2 (but not, of course, the R^2).

Table 4 (continued)

Excluded Variable(s)	Steers		Heifers	
	Rockhampton	Toowoomba	Rockhampton	Toowoomba
Weight	4.91 [3]***	2.04 [3]	2.73 [1]	2.62 [1]
Fat score	6.69 [3]***	10.14 [3]***	5.07 [2]***	2.33 [3]
Weight·fat	3.83 [3]***	1.66 [3]	2.96 [1]*	2.34 [2]
(All weight, fat)	5.24 [9]***	4.47 [9]***	5.40 [4]***	2.29 [6]**
Muscle score	1.99 [3]	14.25 [3]***	2.46 [2]*	1.79 [3]
Muscle·weight	2.59 [3]*	0.85 [4]	0.91 [3]	2.56 [3]*
Muscle·fat	2.40 [3]*	4.28 [3]***	3.70 [3]	1.37 [3]
(All muscle)	6.44 [9]***	12.10 [10]***	7.37 [8]***	1.88 [9]*
Breed	2.72 [5]**	0.82 [6]	0.90 [6]	0.81 [5]
Origin	2.78 [3]**	2.53 [3]*	0.16 [3]	0.42 [3]
Horns	1.28 [1]	8.54 [1]***	0.35 [1]	0.01 [1]
Uniformity	1.81 [1]	0.33 [1]	0.01 [1]	2.09 [1]
Number in lot	20.73 [1]***	2.28 [1]	2.41 [1]	2.27 [1]
Sequence	3.28 [3]**	0.91 [3]	1.84 [3]	2.02 [1]
Auctioneer	0.94 [6]	NR	3.29 [6]***	NR
Feed	3.47 [1]*	6.23 [1]***	NR	0.08 [1]
Sex	NR	NR	NR	NR
Sale	0.04 [1]	NR	3.75 [1]***	NR
RESET(2)	3.44*	3.74*	3.82*	1.12
RESET(3)	2.43*	2.04	2.88*	0.56
RESET(4)	1.63	1.79	2.26	0.38
DW	1.64	1.69	2.09	2.11
R^2 (R^2 adjusted)	0.782 (0.748)	0.721 (0.674)	0.645 (0.501)	0.734 (0.591)
Sample Size (number of lots)	256	242	119	81

Number in bracket [ ] indicates number of excluded variables
NR denotes that the variable was not relevant
*** significant at 1% level
** significant at 5% level
* significant at 10% level
# The figures reported are F-statistics, formed by excluding subgroups of variables from the full model including all relevant interaction terms.

The results presented in Table 3A suggest that for all age/sex types of cattle and at both auction sites, the characteristics not currently reported by the QLMRS but included in this study have the potential to significantly improve the information content of market reports, in some cases, to a spectacular extent. For example, model C, incorporating the QLMRS variables with interactions, explained under 14 per cent of the variation in prices for Yearlings at Rockhampton. However, with the inclusion of the additional characteristics, the full model A, explained over 50 per cent (Table 3A).

Table 5: Estimated premiums and discounts derived from the full model excluding interactions (Model B) - t-statistics shown in brackets

Variable(s)	Cows		Yearlings	
	Rockhampton	Toowoomba	Rockhampton	Toowoomba
Wt range 1	Used as base	Used as base	Used as base	Used as base
Wt range 2	-0.013 (-0.81)	0.018 (0.97)	0.006 (0.42)	0.010 (0.95)
Wt range 3	-0.003 (-0.18)	0.037 (1.80)*	NR	0.008 (0.44)
Wt range 4	0.004 (0.15)	0.041 (1.84)*	NR	NR
Fat score 1	-0.124 (-3.90)***	-0.130 (-4.50)***	NR	NR
Fat score 2	-0.046 (-3.11)***	-0.076 (-5.70)***	-0.028 (-1.72)*	-0.094 (-7.93)***
Fat score 3	Used as base	Used as base	Used as base	Used as base
Fat score 4	0.018 (1.26)	0.041 (3.15)***	0.036 (0.85)	0.028 (1.45)
Fat score 5	0.016 (0.51)	0.013 (0.76)	NR	NR
Fat score 6	NR	-0.171 (-6.43)***	NR	NR
Muscle A	NR	NR	NR	NR
Muscle B	0.012 (0.39)	0.021 (0.85)	0.078 (2.76)***	0.046 (4.08)***
Muscle C	Used as base	Used as base	Used as base	Used as base
Muscle D	-0.041 (-2.90)***	-0.039 (-3.11)***	-0.045 (-3.18)***	-0.040 (-2.52)**
Muscle E	-0.021 (-0.80)	-0.069 (-1.68)*	0.017 (0.32)	NR
Breed 1	0.000 (0.00)	0.001 (0.06)	0.012 (0.28)	-0.006 (-0.61)
Breed 2	-0.098 (-2.75)***	-0.098 (-3.07)***	0.062 (1.22)	-0.003 (-0.14)
Breed 3	0.002 (0.13)	0.005 (1.10)	0.036 (1.98)**	-0.025 (-0.52)
Breed 4	-0.002 (-0.14)	-0.012 (-0.07)	-0.003 (-0.08)	0.013 (0.69)
Breed 5	NR	0.035 (1.00)	NR	NR
Breed 6	-0.007 (-0.47)	NR	-0.001 (0.08)	-0.042 (-1.15)
Breed 7	-0.029 (-1.07)	0.033 (1.07)	0.087 (1.82)*	-0.028 (-1.42)
Breed 8	Used as base	Used as base	Used as base	Used as base
Local	Used as base	Used as base	Used as base	Used as base
Origin 1	-0.016 (-0.83)	0.008 (0.64)	-0.025 (-0.99)	-0.022 (-2.06)**
Origin 2	0.020 (1.39)	0.022 (1.35)	0.025 (1.22)	-0.024 (-1.53)
Origin 3	0.036 (1.94)*	0.050 (3.13)***	0.008 (0.32)	-0.039 (-1.55)
Horns absent	Used as base	Used as base	Used as base	Used as base
present	-0.024 (-1.71)*	0.008 (-0.64)	-0.007 (-0.24)	-0.007 (-0.39)

NR denotes that the variable was not relevant
*** significant at 1% level
** significant at 5% level
* significant at 10% level

5.2 Relative Importance of and Premiums/ Discounts Paid for the Individual Characteristics

The results in Table 3A suggest that some or all of the characteristics included in models A and B, but not currently reported by the QLMRS, could have a statistically significant contribution to explaining price variation at live cattle auctions. Table 4 presents the results of F-tests by which the impor-

Table 5 (continued)

Variable(s)	Steers		Heifers	
	Rockhampton	Toowoomba	Rockhampton	Toowoomba
Wt range 1	Used as base	Used as base	Used as base	Used as base
Wt range 2	0.045 (6.68)***	0.021 (1.42)	-0.013 (-1.22)	0.006 (0.22)
Wt range 3	0.059 (7.42)***	0.007 (0.41)	NR	NR
Wt range 4	0.077 (9.45)***	-0.007 (-0.40)	NR	NR
Fat score 1	NR	NR	NR	NR
Fat score 2	0.053 (2.50)**	-0.108 (-5.62)***	-0.074 (-3.93)***	-0.134 (-3.83)***
Fat score 3	Used as base	Used as base	Used as base	Used as base
Fat score 4	0.036 (5.35)***	0.051 (4.25)***	0.002 (0.16)	-0.006 (-0.19)
Fat score 5	0.011 (0.28)	0.020 (1.20)	NR	-0.067 (-1.47)
Fat score 6	NR	NR	NR	NR
Muscle A	NR	0.095 (3.24)***	NR	NR
Muscle B	0.033 (3.81)***	0.060 (5.94)***	0.052 (3.69)***	0.067 (1.27)
Muscle C	Used as base	Used as base	Used as base	Used as base
Muscle D	-0.026 (-4.16)***	-0.089 (-6.13)***	-0.051 (-4.69)***	-0.023 (-0.86)
Muscle E	-0.117 (-2.66)***	NR	NR	NR
Breed 1	-0.028 (-2.31)**	-0.003 (-0.29)	0.008 (0.42)	0.010 (0.33)
Breed 2	NR	-0.005 (-0.24)	0.034 (0.96)	NR
Breed 3	0.005 (0.73)	0.027 (0.73)	0.017 (1.42)	-0.010 (-0.12)
Breed 4	0.005 (0.57)	-0.007 (-0.57)	0.013 (0.91)	0.028 (0.78)
Breed 5	NR	NR	0.018 (0.77)	NR
Breed 6	0.011 (1.36)	-0.010 (-0.46)	NR	0.035 (0.41)
Breed 7	-0.036 (-2.72)***	0.005 (0.30)	-0.010 (-0.41)	0.063 (1.19)
Breed 8	Used as base	Used as base	Used as base	Used as base
Local	Used as base	Used as base	Used as base	Used as base
Origin 1	0.018 (1.94)*	0.007 (0.55)	-0.006 (-0.36)	-0.016 (-0.50)
Origin 2	0.005 (0.59)	0.010 (0.67)	0.001 (0.01)	-0.055 (-1.30)
Origin 3	0.017 (2.58)***	0.028 (2.45)	-0.013 (-0.77)	0.021 (0.51)
Horns absent	Used as base	Used as base	Used as base	Used as base
present	-0.002 (-0.34)	-0.023 (-2.61)***	0.011 (0.64)	0.003 (0.11)

NR denotes that the variable was not relevant
*** significant at 1% level
** significant at 5% level
* significant at 10% level

tance of these individual characteristics may be evaluated.[15]

The collinearities in the data set are clear in these results: the F-statistic formed by excluding the broad groups of variables (All Weight, Fat) and (All Muscle)[16] are at times more significant than those formed by excluding any individual set of variables within the broad group (see Table 4, Yearlings, Steers and Heifers at Rockhampton, in particular).

[15] Systematic sub-models of model A above, formed by excluding one variable or group of variables relating to an individual characteristic from the full model, were then estimated. Thus, for cows at Toowoomba (Table 4, column 2, row 2), the F-statistic formed by excluding the five fat variables is 17.89, indicating that the effect of fat on price is significant at the 1 per cent level.

[16] The F-statistic for (all Weight, Fat) and (all Muscle) is that formed by excluding all the variables of that group.

Table 5 (continued)

Variable(s)	Cows		Yearlings	
	Rockhampton	Toowoomba	Rockhampton	Toowoomba
Uniformity	0.019 (1.91)*	-0.012 (-1.21)	-0.006 (-0.53)	0.003 (0.17)
Number in lot	0.001 (1.13)	0.003 (1.69)*	0.003 (1.82)*	0.004 (2.74)***
Sequence	-0.0009 (-1.41)	0.0016 (2.42)**	-0.0023 (-0.91)	0.00001 (0.09)
Sequence^2	0.00001 (2.03)**	-0.00001 (-2.15)**	0.00004 (0.82)	
Sequence^3				
Auctioneer 1	Used as base	NR	Used as base	NR
Auctioneer 2	0.013 (0.71)	NR	0.028 (1.20)	NR
Auctioneer 3	0.001 (0.03)	NR	-0.037 (-0.85)	NR
Auctioneer 4	0.012 (0.59)	NR	0.014 (0.43)	NR
Auctioneer 5	0.031 (1.47)	NR	-0.042 (-1.91)*	NR
Auctioneer 6	0.043 (1.52)	NR	0.008 (0.23)	NR
Auctioneer 7	-0.021 (-0.90)	NR	-0.026 (-0.78)	NR
Second sale	-0.051 (-3.64)***	NR	-0.024 (-1.12)	NR
Feed - Grass	NR	NR	Used as base	Used as base
Grain			-0.003 (-0.08)	0.057 (2.60)***
Sex - Male	NR	NR	Used as base	Used as base
Female			-0.036 (-2.02)**	-0.031 (-3.41)***
Constant	0.942 (20.25)***	0.911 (20.51)***	1.145 (29.27)***	1.267 (24.66)***
RESET (2)	2.43	0.23	4.31**	0.72
RESET (3)	1.88	0.83	3.91**	0.44
RESET (4)	1.27	0.63	3.00**	0.29
DW	1.99	1.91	2.19	1.89
R^2 (R^2 adjusted)	0.427 (0.340)	0.727 (0.677)	0.476 (0.312)	0.570 (0.529)
Sample Size	237	164	122	243

NR denotes that the variable was not relevant
*** significant at 1% level
** significant at 5% level
* significant at 10% level

The results concerning the influence of the characteristics not currently reported by the QLMRS are not always clear cut with some differences being found between sex/age classes and between locations. However, some broad conclusions can be drawn.

Muscle Score (both on its own and its interactions with weight and fat) is a highly significant characteristic in explaining price variation for all classes of cattle at both centres. Only for Heifers at Toowoomba does muscle score appear to be only marginally significant. (See Table 4.)

To further illustrate the importance of muscle score, a fifth model was estimated (see Table 3B). The addition of muscle score to the QLMRS model including interactions (model C) raises the

Table 5 (continued)

Variable(s)	Steers		Heifers	
	Rockhampton	Toowoomba	Rockhampton	Toowoomba
Uniformity	0.006 (1.14)	0.003 (0.31)	-0.003(-0.29)	0.052 (2.05)**
Number in lot	0.002 (4.04)***	0.002 (1.93)*	0.001 (0.66)	0.006 (1.61)
Sequence Sequence^2 Sequence^3	-0.0014 (-2.19)** 0.00002 (1.82)* -0.0000 (-1.52)	0.0023 (1.85)* -0.00004(-2.05)** 0.000000(2.17)**	0.005 (1.95)** -0.0002(-2.13)** 0.000002(1.94)**	0.0014 (1.02)
Auctioneer 1 Auctioneer 2 Auctioneer 3 Auctioneer 4 Auctioneer 5 Auctioneer 6 Auctioneer 7	Used as base -0.011 (-1.46) 0.007 (0.59) 0.000 (0.01) -0.007 (-0.57) -0.001 (-0.10) -0.011 (-1.13)	NR NR NR NR NR NR NR	Used as base -0.002 (-0.09) -0.042 (-2.38)** 0.006 (0.26) 0.020 (1.24) 0.014 (0.51) -0.014 (-0.43)	NR NR NR NR NR NR NR
Second sale	-0.007 (-1.09)	NR	-0.029 (-2.32)	NR
Feed - Grass Grain	Used as base 0.034 (2.49)**	Used as base 0.052 (2.02)**	NR	Used as base 0.061 (1.03)
Sex - Male Female	NR	NR	NR	NR
Constant	1.147 (53.65)***	1.188 (29.75)***	1.109 (32.25)***	0.945 (10.38)***
RESET (2) RESET (3) RESET (4)	3.18* 1.60 1.35	1.71 0.92 0.79	3.01* 3.20** 2.25	1.51 2.36 1.60
DW	1.67	1.58	2.00	2.06
R^2 (R^2 adjusted)	0.764 (0.731)	0.681 (0.644)	0.580 (0.456)	0.647 (0.530)
Sample Size	256	242	119	81

NR denotes that the variable was not relevant
*** significant at 1% level
** significant at 5% level
* significant at 10% level

proportion of price variation explained by between 3 percentage points (for Cows at Toowoomba) and 25 percentage points (for Heifers at Rockhampton).

Muscle score is by far the most important additional characteristic investigated, as judged by its ability to explain the price variation remaining after the effect of the QLMRS-reported characteristics has been removed. Its significance over the range of cattle types at both centres along with its ability to increase substantially the explanatory power of the model, suggests that it would be a useful addition to the characteristics reported by the QLMRS.

As to the premiums and discounts placed on muscling by buyers, it would be wrong to claim that the coefficients for muscle score, given in Table 5, are 'true' in any absolute sense. The omission of the often significant interaction terms and the related potential problems of model mis-specification argue against this conclusion.[17] However, the estimates generally have the correct sign and magnitude, with better muscle scores (A and B) attracting a premium and poorer muscle scores (D and E) being penalised as compared with the base level of muscle score C. The extent of the premiums for the high muscle score animals and penalties for the low muscle scored animals appears to be large.

Breed type (as a group of up to seven dummy variables) is not generally significant, the exception being for Cows and Steers at Rockhampton (Table 4). Its inclusion in the model raises the proportion of price variation explained by modest amounts (1 to 7 percentage points), with the greatest increases being for yearlings. However, in Table 5, it is clear that some breeds do attract a modest premium or discount. Angus (Breed 2) Cows appear to be heavily discounted (10c/kg), while Brahman (Breed 3) Yearlings attract a modest premium in Rockhampton (3c/kg). This is consistent with the preference for the Brahman in the tropical Central region. The effect of breed on price does not appear to be strong enough or consistent enough to justify the inclusion of breed in market reports.

Origin of the cattle also does not appear to be generally significant, although there is evidence that it is more significant for Toowoomba sales, with Origin 1, the Darling Downs, being discounted for Yearlings (2c/kg) and Origin 3, the Far West Channel Country attracting a premium for Cows.[18] The impact is again greater for the cattle destined for domestic consumption, its inclusion for Yearlings in Toowoomba increasing the proportion of price variation explained by 5 percentage points.

Presence of horns appears to have little impact on price, except for Steers at Toowoomba where price is discounted by 2c/kg.

Uniformity of the lot is not generally significant, the exception being for Heifers at Toowoomba. This result may be spurious, in the light of the consistency of the results for other age/sex groupings at both auction sites.

There is some evidence of a positive relationship between price and **number in the lot**, with price increasing by around 0.2-0.4c/kg for every extra head of cattle in a lot. The effect is not consistently significant for all types of cattle or for both saleyards. (See Tables 4 and 5)

Order of sale or **sequence** variables, as indicated above, were incorporated to capture any dynamics in prices over the period of the sale. Unlike the other variables, there is little prior information about the expected signs and functional form of this variable. The specific form of the variable included in the models was thus determined empirically. Quadratic and cubic functions of the order of sale appeared to provide the 'best fit' as measured by the RESET, DW and R^2 statistics. The sequence in which the lots were offered for sale was only significant (as a group of variables) in three out of the eight models estimated (Table 4). The coefficient estimates given in Table 5 show no common pattern and cannot be readily interpreted.[19]

Auctioneers in Rockhampton appear to be equally successful in extracting the maximum price for their cattle. Only for steers, and to a lesser extent, yearlings was the group of auctioneer variables significant. (The predominantly insignificant differentials between the prices made by the various auctioneers can be seen in Table 5.) No one auctioneer is found to consistently attract higher or lower prices for all cattle types.

5.3 Model Specification

Some slight misspecification problems are indicated by the values of the RESET and DW statistics, particularly for yearlings and steers (see Table 4). Alternative functional forms were estimated but these were inferior to those reported. The problem seems to be the specification of the order of sale variable and this will be the subject of further detailed investigation. The specification of the

[17] The generally insignificant RESET tests suggest that model mis-specification in the absence of the interaction terms, as shown in Table 5, is not a severe problem.

[18] Cows from this region are less likely to be dairy cattle than from the other regions.

[19] Much more detailed work, both theoretical and empirical, on the dynamic structure of prices within auctions is required and is currently being investigated by the first author.

models is not seriously impaired by the omission of the interaction terms, as indicated in Table 5, although some reduction in the explanatory power of the models is indicated by the reduction in the adjusted R^2 (see Table 3A).

5.4 Remaining Unexplained Price Variation

A large proportion of price variation remains unexplained, particularly in Rockhampton, even after all the information on the additional characteristics has been included. Yearlings have the largest amount of price variation unexplained - half of the total variation in Rockhampton and a third in Toowoomba. Even for those sectors of the market in which the estimated models appear to perform reasonably well, between a fifth and a quarter of price variation remains unexplained.

Coefficients of variation were calculated for each of the four sex/age categories to determine whether prices at Rockhampton were fundamentally more variable than those in Toowoomba. The analysis suggested the opposite: that is, Toowoomba prices exhibited the greater relative variability. The coefficient of variation was lower in Rockhampton for all four groups, and was lower for Yearlings than any other group.[20] This suggests that there may be a large component of 'noise' in the price discovery process for cattle, especially Yearlings and Cows sold at auction in Rockhampton. Market reports for these sectors may be of limited usefulness, especially in their current format, indicating only broad price movements between different categories. As indicated in Table 3A, for Yearlings, Cows and Heifers at Rockhampton, the characteristics currently included the QLMRS reports account for less than a quarter of the variation in the prices paid for each lot of cattle.

6. Conclusions

This study has revealed that there are potentially important characteristics which affect the price of live cattle in Queensland which are not currently collected by the QLMRS. In particular, the addition of muscle score to the hedonic price model increases its explanatory power significantly. This is the case for all types of cattle for which data were recorded and for both sites.

The premiums and discounts which the different muscle scores attract cannot be clearly determined because of the strong collinearities existing in the data set between the group of variables, weight, fat score and muscle score. Provisional estimates indicate that the penalties per unit decrease in muscle score could be as high as 9c/kg for steers and average around 4c/kg for other types of cattle. Other characteristics, such as breed type, district of origin, presence of horns and lot uniformity, are found to have a limited and variable impact on prices paid.

The finding of a significant influence of a characteristic on price is not to be construed as a suggestion that data on this characteristic should be collected by the QLMRS market reporters. This study required a minimum of two, and more comfortably three reporters, to collect all the necessary information. This requirement would lead to an escalation of costs at a time when the Reporting Services are already financially pressured. Also it is not clear that much extra information would be gained by producers when faced with a possibly confusing plethora of premiums and discounts, associated with different characteristics. This study has indicated that these premiums and discounts may be quite variable across the State and across sex/age types. Over time, the premiums and discounts would be expected to be subject to further variation as, particularly, supply conditions changed.

However, the consistency and magnitude of the effect of muscle score found by this study could warrant further investigation to determine the viability of either adding this characteristic to the regular market reports or producing an additional, less regular, report on the premiums and discounts which could be expected by producers. Further investigation would be required to establish the stability of these premiums and discounts over time, and further statistical testing carried out to determine whether the intrinsic multicollinearity problems preclude their estimation with any greater precision than that reported in this paper.

[20] The calculated coefficients of variation were:

	Cows	Steers	Heifers	Yearlings
Toowoomba	10.1%	9.4%	10.1%	9.3%
Rockhampton	9.3%	7.5%	7.4%	6.5%

The high proportion of price variation which remains unexplained, especially for some sectors of the market, may be a cause for concern, indicating potentially serious pricing inaccuracies in the live cattle auction system. With pricing accuracy a prerequisite for pricing efficiency, this analysis suggests that liveweight auctions may not represent an efficient price discovery mechanism for cattle.

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Data Appendix

The cattle auctions for which data were collected were held on June 18 and 25 at Rockhampton and on July 2 and 3 in Toowoomba. The collection of some of the data required specialised assessment skills, (for example, that for muscle score and fat score). One of the researchers (John Rolfe) is an accredited AUS-MEAT assessor and cattle producer.

Fat Depth

The speed of the sales precluded the estimation of actual fat depth of the cattle. Instead an average fat score for each lot of cattle was recorded according to the same classification used by the QLMRS. These are:

Fat Score	Fat Depth in mm (measured at rump)
1	0 - 2
2	3 - 6
3	7 - 12
4	13 - 22
5	23 - 32
6	over 32

Muscle Score

The muscle scoring followed that used by AUS-MEAT, with 5 possible scores, ranging from A (good) to E (poor).

Breed Type

Eight different breed categories were used in the analysis:

- five pure-breeds - Hereford (breed 1); Angus (breed 2); Brahman (breed 3); Santa Gertrudis (breed 4); and Charolais (breed 5);
- two cross-breeds - Brahman X (breed 6) and Hereford X (breed 7); and
- other (breed 8).

District of Origin

Four areas were identified for each auction site. These areas were defined to reflect both the distance travelled by the animals on the way to the auction and the quality of feed at that origin. The local area was taken as the base for the analyses for both centres, with dummy variables created for the three remaining areas. These are:

Origin	Rockhampton	Toowoomba
1	Coastal	Darling Downs
2	Brigalow	Western Plains
3	Brigalow Flatlands	Far West Channel Country

Uniformity

Uniformity of the lot was assessed on a three point scale, with 1 representing the most heterogeneous and 3 the most homogeneous lots.

Auctioneer

Seven different stock agents were represented at each of the two Rockhampton sales. The effect of auctioneer was measured relative to the first auctioneer of the sale. At each of the Toowoomba sales, only one agent was represented.

Weight

The weight ranges used for the analysis differ according to the sex/age classification and follow those used by the QLMRS.

Weight Range	Yearlings (kg)	Cows (kg)	Steers (kg)	Heifers (kg)
1	0 - 280	0 - 320	0 - 440	0 - 440
2	280.1 - 370	320.1 - 420	440.1 - 500	over 440
3	over 370	420.1 - 520	500.1 - 550	
4		over 520	over 550	