THE IMPORTANCE OF NON-LMRS REPORTED FACTORS IN THE DETERMINATION OF CATTLE PRICES IN QUEENSLAND*

Christine H. Williams and John Rolfe
Departments of Economics, The University of Queensland, and
University College of Central Queensland (Emerald)

ABSTRACT

The Livestock Market Reporting Service was established in Queensland over ten years ago with the aim of improving the quantity and quality of information available to market participants in the live cattle auctions. Weekly reports indicate the prices of different types of cattle, categorised by their sex, age, weight and fat cover. Previous research has indicated that these factors, reported by the Market Reporting Service, do not account for all the price variation at liveweight auctions. Other factors which may be important in determining the price or cattle include the estimated muscle score, breed type, position in the sale, the presence of horns, the uniformity of the lot and the origin of the cattle.

Data on these potentially important characteristics have been collected for a number of auctions in Queensland. This paper analyses the contribution of these factors in explaining the wide price variation found in cattle prices and compares it with the explanatory power of the LMRS-reported characteristics. A hedonic price model is used to analyse the implicit value of the characteristics and to assess whether this valuation varies between the Central and South-East regions of the State.

* Research on this project was supported by a Special Projects Grant from the University of Queensland.

Introduction

Live cattle auctions are central to the price setting mechanism for live cattle in Queensland. Not only does the auction act as a major marketing channel for the sale of slaughter cattle but the prices set at auction form the basis for prices set at the other major marketing channel, direct sales to meat processors. (Hall, 1981) The importance of the role of the liveweight auction was recognised in the late 1970s when Livestock Market Reporting Services were established throughout Australia. Their role is to disseminate information about prices of livestock at the major sales centres in each State.

Live cattle are a heterogeneous commodity where the characteristics of the individual beast or lot differentiate them from other cattle offered for sale. Prices vary because of this heterogeneity. The market reports compiled by the Queensland Livestock Market Reporting Service (QLMRS) contain information about prices of cattle sold, with the reports disaggregated on the basis of five characteristics: age, sex, weight, fat cover and whether the animals had been grass or grain fed. An examination of the information content of QLMRS market reports in 1989 revealed that, while the explanatory power of the QLMRS data was reasonably strong for some types of cattle and some saleyards, a significant proportion of price variation was left unexplained. (Williams <u>et</u> <u>al</u>., 1989)

Two possible explanations were advanced as to why the market report information could not fully explain price variations. The first and most likely is that there are unreported characteristics which are of importance to the buyers and which therefore contribute to explaining the price of any particular lot of cattle. The second possibility is that the market is not operating efficiently and that there is inherent price variability in the auction system. This paper attempts to test these two hypotheses concerning the price behaviour of the live cattle auction by examining information on additional potentially important characteristics collected at four cattle auctions in Winter 1990.

An appropriate framework for analysing the contributions of these characteristics to auction prices is hedonic price analysis.[1] 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 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, statistical analysis can be used to estimate the implicit values that buyers place on each characteristic or attribute.

In addition to determining which characteristics appear to be important in the determination of prices, this paper provides an indication of the implicit values placed on these characteristics by buyers.

Characteristic Requirements of Buyers

Buyers operating at auctions purchase cattle according to firstly, the classifications set by end-users, secondly, the perceived quality of the meat, and thirdly the perceived yield of meat from the beast[2]. These three objectives will be satisfied by an appraisal of the characteristics of the cattle. A particular characteristic will often be important to each of the objectives, although the importance will vary between them and may produce conflicting results. For instance, fat may have a positive influence on carcass quality but a negative influence on carcass yield. The importance and effect of these characteristics on price is thus uncertain. For export-type cattle the most important objective would appear to be classification, whereas cattle for domestic markets are likely to be assessed first on quality considerations. The market is roughly divided between export and domestic demands. Older and/or heavier cattle (cows, heavy steers and bulls) are supplied principally for export, while younger stock (vealers, yearlings, light steers and heifers) dominate the domestic market.

Characteristics used in classification

Characteristics important for categorising cattle into end-user classifications are age/sex, weight, fat cover and muscle score (or butt profile). Export orders, principally from the United States and Japan, use broad categories to specify the required product. Buyers will use these broad categories for estimating the weight range and fat depth of cattle rather than assessing these characteristics on a continuous basis. Domestic orders tend not to make such general categorical distinctions between characteristics. There are two main reasons.. The first is that the domestic market demands 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 conformation with specific categories.

Characteristics affecting quality

Meat quality is important to buyers. It is the principal determinant of meat price in the domestic market and factors such as fat colour, meat colour and marbling can be categorical requirements in the export market. Characteristics that auction buyers could consider important include the presence of grain feeding, fat score, breed type, muscle score as an indicator of weight-for-age, the potential for bruising as indicated by temperament, the presence of horns, and the distance travelled, and feed availability as indicated by district of origin and distance travelled.

Fat is generally seen as a desirable characteristic. The relationship between price and the characteristics of fat score, grain feeding and muscling is expected to be a positive one. The breed of cattle may be significant if buyers believe some breeds produce higher quality meat 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.

Characteristics affecting yield

The physical yield of meat from a beast 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 yield well. Characteristics that buyers could consider important are age, sex, fat depth, muscle score, breed type, the type of feeding (including grain) and the likelihood of bruising. Cows and cattle that are aged or very fat tend to yield poorly. A positive relationship will probably exist between price and muscle score, grain feeding and high quality feed. Males are generally preferred because of the risk of pregnancy and subsequent low yields associated with females. There may be a premium for feed lot heifers because these are effectively guaranteed free of pregnancy. Again, breed type could be significant if buyers held strong perceptions about their yield characteristics. There is likely to be a negative relationship between price and the presence of excess fat and the likelihood of bruising, both factors that reduce yield.

Previous Research

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 included in these studies are: age, sex, weight, fat depth, feed type, breed, district of origin, lot size, presence of horns and the position of the lot within the sale.

The results of the different studies are often inconsistent. For example, weight was not found to be significant by Todd and Cowell or by Porter and Todd, but was found significant by Williams et al.. This may be explained by the different age/weight of animals investigated, as discussed in Williams et al.. However another reason may be the different techniques used to investigate the significance of these characteristics.

Two basic techniques have been used to analyse the importance of different characteristics on the price of cattle. The technique used by Porter and Todd was to first estimate the full equation including all potentially important characteristics of the cattle sold, and then systematically estimate a series of equations in which one characteristic is omitted from the full equation. F-tests were then carried out to see whether the omitted characteristic was significant in its effect on price. Todd and Cowell used 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 set to be analysed is beset by multicollinearity in the potential set of 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 regression's explanatory power. 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 study, the use of multiple regression techniques in the presence of multicollinearity has associated with it the classic problems of inflated variances of the affected 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, and Porter and Todd may be explained by the presence of multicollinearity in their data sets. Porter and Todd 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. Multicollinearity problems were encountered in the current data set and these are discussed below.

Data

Data for this study were collected at auctions at Toowoomba and Rockhampton during Winter 1990.[3] Prices for several hundred lots of cattle were recorded (in cents per kilogram liveweight) along with measurements of a set of the characteristics possessed by each lot. Characteristics reported for all saleyards include age/sex, weight, fat cover[4], muscle score[5], breed type[6], district of origin[7], number in lot, uniformity of the lot[8], whether grain fed, the presence of horns and the position of the lot in the sale[9], while for Rockhampton, additional information was collected on the auctioneer responsible for the sale of each lot[10].

Actual liveweights were obtained for each lot after the sale. However the analysis is carried out using weight as a categorical variable.[11] Buyers estimate weights when bidding, so some discrepancies could exist between their subjective assessments and the actual weights. This difference is minimised by the use of categorical variables. More importantly, because of order requirements, particularly export orders, buyers tend to assess lots into weight ranges instead of estimating weight to the nearest kilogram.

Fat score, muscle score and uniformity of lot were estimated by the data collectors. It is possible that their estimates differed from those of the buyers, but because categories were used, it is anticipated that any differences would be minimal.[12] 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 then 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 assessed by the data collectors and this data are assumed to be accurate. The area of origin was split into three broad groups, to reflect both the distance travelled and the quality of feed. The number in each lot, the position of the lot in the sale, the presence of horns and whether grain fed or not were characteristics that were straight forward in collection.

Methodology

The empirical section of this paper deals with the analysis of individual lot data to explain variations in prices by variations in the characteristics of the cattle in question. Multiple regression analysis is used to estimate a hedonic price function.

The hedonic price model

A hedonic price function 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 economic agents' behaviour 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)].[13]

As discussed in Williams et al.(1989), the analysis 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 the two sales centres.[14]

The general form of the estimated model estimated is:

$$P_i = \Sigma X_{ij} p_j + e_i$$

where P_i is the price of the heterogeneous lot i;
p_0 is the price of the reference lot of cattle;
X_{ij} is the quantity of the jth characteristic provided by the ith lot (measured relative to the quantity of that characteristic in the reference type);
and p_j is the premium/discount associated with a unit change in the amount of characteristic provided by lot i compared with the reference lot.

Included in the set of regressors are the characteristics on which data were collected and interaction terms between weight and fat depth, weight and muscle score, and fat and muscle score.

Multicollinearity problems

Severe problems of multicollinearity were experienced in the analysis of the collected data. 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.

Identification of the offending variables

The inflated variances caused by multicollinearity affect only those variables affected by the dependencies within the set of variables. The initial step then 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 of the scaled matrix of the explanatory variables, $X'X$.[15] The ith condition index, CI is defined to be

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

where λ_1 is the smallest eigenvalue, and
λ_i is the ith eigenvalue of the normalised $X'X$.

Belsley *et al.*(pp100-105) show that moderate to strong dependencies are associated with condition indices between 30 and 100. Corresponding to each high condition index is a strong dependency in the X′X matrix. Severe multicollinearity is indicated by condition indices greater than 100. This level of multicollinearity 'causes substantial variance inflation and great potential harm to regression estimates'(Belsley *et al*, p153).

If the existence of such multicollinearity is indicated by the condition indices, 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.[16] For high condition indices, the presence of high variance proportions for two or more coefficients indicates that a relationship may exist between those variables. Belsley *et al.* provide a simple rule of thumb: that estimates are considered to be degraded by multicollinearity when more than 50% of the variance of two or more coefficients is associated with a single high condition index.

Conducting these tests on the current data set revealed condition indices 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, those are the only variables involved in the collinearities. The other characteristics' coefficient estimates can be regarded as 'clean', that is, unaffected by inflated variances and the related instability of the estimates.

The solution

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 here.[17] 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, p874] 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 made up the collinearities are composite. The problem of the inflated variances is removed but the coefficient estimates are no longer 'pure'.

By excluding the interaction terms, all troublesome multicollinearity problems are removed, with the condition indices 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 condition index from 170 to 17, for heifers at Rockhampton.

The approach used here is to, first, estimate the full hedonic price model, complete with interactions, and test this for the significance of the additional non-LMRS reported characteristics. The F-test technique of Porter and Todd can be used to test whether a characteristic has a significant effect on price. It should be noted that the apparent non-significance of one of the problematical variables (weight, fat, muscle and their interactions) must be disregarded. No conclusion can be made about those variables insignificance. The results of these tests are shown in Tables 1 to 4.

Following this, an attempt is made to estimate how much extra price variation the non-LMRS reported characteristics can explain, in addition to that already explained by the LMRS-reported characteristics. The rationale for this is to indicate which of these factors, if any, may be a useful addition to the market reports.[16] This is discussed below.

Finally, some indication is given of the implicit values of the characteristics revealed by the hedonic price model. These will be most reliable for those variables unaffected by the multicollinearity. The models used to estimate these hedonic prices have had the interaction terms removed. These are reported in Tables 5 to 8. It should be noted here that the exclusion of the interaction terms in some of the equations reduces the goodness-of-fit. Further analysis remains to be done on this section. Inclusion of the interaction terms, with their related multicollinearity makes the coefficients for weight, fat and muscle score uninterpretable. The equations reported here do have coefficients which are 'sensible' and have a clear interpretation.[19]

The Significance and Implicit Value of the Additional Factors

Tables 1 to 4 show the results of the F-tests performed by comparing the full model with individual models, formed by excluding one variable or group of variables relating to an individual characteristic from the full model.

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] are often more significant than those formed by excluding any individual set of variables within the broad group. (See Tables 2 and 4)

The results concerning the influence of the non-LMRS reported characteristics are not always clear cut with some differences found between sex/age classes and region. However, some broad conclusions can be drawn.

Muscle score (both on its own and with its interaction with weight and fat) is a significant factor in explaining price variation for most classes and at both centres. Its inclusion as an explanatory variable raises the explanatory power of the model by between 5% (for cows at Toowoomba) and 58% (for yearlings at Rockhampton). It is by far the most important factor of those collected, as judged by its ability to explain the price variation remaining after the effect of the LMRS-reported factors has been removed. Its significance over the range of cattle types and 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 factors reported on by the QLMRS. It would be wrong to claim that the coefficients for muscle score, given in tables 5 to 8, are 'true'. The omission of the often significant interaction terms and the related problems of model mis-specification preclude this. However the estimates generally have the correct sign and magnitude, with poorer muscle scores being penalised. (Collinearity problems between the weight, fat and muscle variables are apparent most clearly in the equations for steers [Table 7] and cows [Table 5].)

Breed type (as a group of six or seven dummy variables) is not generally significant, the exception being for cows at Rockhampton. However, in Tables 5 to 8, it is clear that some breeds do attract a modest premium or discount. Its inclusion in the model raises the proportion of price variation explained by very modest amounts (2 to 10%), with the greatest increases being for yearlings, dominated by the domestic market. Angus (Breed 2) cows appear to be heavily discounted (8-12c/kg), while Brahman (Breed 3) yearlings attract a penalty in Toowoomba (10c/kg) and a premium in Rockhampton (4c/kg). This is consistent with the different perceptions of the Brahman between the tropical Central region and more temperate South-East region.

Origin of the cattle is significant only for Toowoomba, with Origin 1, the Darling Downs, being discounted for yearlings (3c/kg) and heifers (4c/kg) The impact is again greater for the cattle destined for domestic consumption, its inclusion for yearlings in Rockhampton increasing the R^2 of the model from 0.14 to 0.19.

Horns appear to have little impact on price, except for Heifers and Steers at Toowoomba where price is discounted by 3-4c/kg.

Uniformity of the lot is not genera[illegible] significant.

For Toowoomba, the **number in the lot** does have a significant effect on price, with price increasing as the lot size increases. The limited effect of this variable in Rockhampton is thought to be a result of the differing buying methods. In Rockhampton many pens are split into one or two single lots, representing the pick of the pen, with the remainder sold as a larger lot. This increased quality of the small lots is expected to offset the gain in convenience in handing a few large lots. This lot-splitting is most prevalent for the younger cattle.

Feed type is significant where both grass and grain fed cattle were represented at the sale. Grain-fed steers and heifers at Toowoomba attracted a premium of 7c/kg and 11c/kg respectively. This characteristic is already included in the market reports produced by the QLMRS.

The **auctioneers** in Rockhampton appear to have varied success in extracting the maximum price for their cattle, with the auctioneer variables significant for all types of cattle. (The differentials between the prices made by the various auctioneers can be seen in Tables 5 to 8.) Further analysis is to be undertaken to ensure that this effect is not related to the order of sale. No auctioneer is found to consistently attract higher or lower prices.

Conclusions

This study has revealed that there are important characteristics which affect the price of cattle in Queensland which are not currently collected by the Queensland Livestock Market Reporting Service. In particular, the addition of muscle score to the hedonic price model increases its explanatory power quite significantly. This has be shown to be the case for all types of cattle for which data were recorded and for both centres. The implicit 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 could be as high as 10 to 20c/kg for steers and heifers.

Other characteristics, such as breed type and district of origin are found to more significant for the types of cattle dominated by the domestic market. The prices which buyers for this segment of the market are prepared to pay for yearlings and heifers appear to be more affected by these characteristics which are often perceived to affect meat quality.

The finding of a significant influence on price of many of the extra characteristics on which data were collected is not to be construed as a suggestion that data on all these characteristics should be collected by the 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 information would be gained by producers when faced with a possibly confusing plethora of premiums and discounts, associated with the different characteristics. This study has indicated that these premiums and discounts may be quite variable across the State and across breed types. Over time these may be subject to further variation, a result which cannot be determined by this static analysis. 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.

To conclude it should be noted that 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. Coefficients of variation were calculated for each of the eight groups to determine whether prices at Rockhampton were fundamentally more variable than those in Toowoomba. These showed the opposite result. 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 is a large component of noise in the price-determining process for cattle sold at auction in Queensland. This is particularly marked in the Rockhampton market and in the market for yearlings.

Endnotes

1. This branch of demand/price theory is generally credited to Lancaster (1971), although there were earlier attempts to link demand characteristics with price, for instance Waugh (1928).

2. Requirements of the end users are specific, so individual carcasses will only satisfy certain markets. For example, orders for Jap Ox will accept heavy steers less than four years old with fat score 3 or 4 (fat depth between 7 and 32 millimetres), and a butt profile of A, B or C.

3. The sales recorded were held on June 18 and 25 at Rockhampton, and on July 2 and 3 in Toowoomba.

4. The speed of the sale precluded the estimation of actual fat depth. Instead the average fat score of the lot was recorded, according to the same classification used by the QLMRS. These are:

Fat Score 1 0mm - 2mm
Fat Score 2 3mm - 6mm
Fat Score 3 7mm - 12mm
Fat Score 4 13mm - 22mm
Fat Score 5 23mm - 32mm
Fat Score 6 over 32mm

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

6. Eight different breed types were chosen as representative: Purebred Hereford (Breed 1), Angus (2), Brahman (3), Santa Gertrudis (4), Charolais (5) and Crossbreeds Brahman X (6), Hereford X (7) and Other (8).

7. Four areas were identified for each sales centre, reflecting both the distance travelled by the animals and the quality of feed at that origin. The local area is taken for both sites as the basis for the analysis. Dummy variables were created for the three remaining areas. These are:

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

8. Uniformity was measured on a three point scale:
1 heterogeneous
2 moderately heterogeneous
3 homogeneous.

9. The analysis is carried out separately for each major sex/age group. The position in the sale recorded was thus the position in the sale relative to the other lots of cattle falling into the same age/sex classification.

10. Eight different stock agents were represented at each of the two Rockhampton sales. The effect of auctioneer is measured relative to the first auctioneer of the day. At each of the Toowoomba sales, only one agent is represented, and data on auctioneer was not recorded.

11. The various weight ranges used differ according to the sex/age classification and follow those used by the QLMRS. For yearlings, the groupings used were:

	≤ 280kg
	> 280 and ≤ 370kg
	> 370kg
For cows:	≤ 320kg
	> 320 and ≤ 420kg
	> 420 and ≤ 520kg
	> 520kg
For steers:	≤ 440kg
	> 440 and ≤500kg
	> 500 and ≤550kg
	> 550kg
For heifers:	≤ 440kg
	> 440kg

12. Analysis by Naughton (1980) and Naughton and Holland 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.

13. The functional form used for this analysis is linear for the categorical variables and loglinear for the continuous variables. Price is used in linear form. Reset tests were used along with various heteroskedasticity tests to test for specification error.

14. 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.

15. 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.

16. The variance of each regression coefficient can be split into a sum of components, each associated with one and only one eigenvalue. The *ij*th 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 *i*th regression coefficient associated with the *j*th eigenvalue.

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

18. For example, the Department of Agriculture and Rural Affairs in Victoria have produced a summary of price differentials for cattle which includes the price differentials between cattle of different muscle scores.

19. A possible next step is to impose these values on the equation and re-estimate the full model with interaction terms included and these restrictions imposed.

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%

Bibliography

Belsley, D., E.Kuh, and R.E.Welsh (1980), Regression Diagnostics, Wiley, New York.

Hall J.W.A.(1981), An Analysis of Cattle Prices at Auction and at Weight and Grade, M.Agr.Sc. Thesis, University of Queensland, Brisbane, Australia.

Hogan J.C. and M.C.Todd (1979),'Empirical Tests of Spatial and Structural Effects on Cattle Auction Prices', Australian Journal of Agricultural Economics 23(3), 176-190.

Judge,G.G, R.C.Hill, W.E.Griffiths, H.Lutkephol and T.C.Lee (1988), Introduction to the Theory and Practice of Econometrics, John Wiley & Sons, New York.

Lancaster K.(1971), Consumer Demand: A New Approach, Columbia University Press, New York.

Naughton J.(1980),'The Accuracy of Market Reporters in the Estimation of Carcass Weight and Fat Cover for Cattle', Review of Marketing and Agricultural Economics 48(3), 169-174.

Naughton J. and Holland B.J.(1982),'The Accuracy of Market Reporters under Liveweight Selling Conditions', Review of Marketing and Agricultural Economics 50(3), 285-295.

Park S.H.(1979),'Variability in the Appraisal of Beef Carcass Characteristics and their Relationship with Prices in Australia', M.Ec. Thesis, University of New England, N.S.W.

Porter D. and M. Todd (1985),'The Effect of Carcass Quality on Beef Carcass Auction Prices', Australian Journal of Agricultural Economics 29(3), 225-234

Todd M.C. and M.D.Cowell(1981),'Within-sale Price Variation at Cattle and Carcass Auctions', Australian Journal of Agricultural Economics 25(1), 30-47.

Waugh F.V.(1928) Quality Factors influencing Vegetable Prices, Journal of Farm Economics 10, 185-196.

White K.J., S.A.Haun, N.G.Horsman, and S.D.Wong(1988), Shazam Econometrics Computer Program, User's Reference Manual, Vers 6.1, McGraw-Hill, New York.

Williams C.H., J.W.Longworth and I.F.Whan (1989), 'The Information Content of Price Reports of Queensland Cattle Auctions', Discussion Paper 15, Department of Economics, University of Queensland.

Williams C.H.(1989),'The Choice of Functional Form for Hedonic Price Functions: an Application of the Box-Cox Transformation to Cattle Prices in Queensland', Discussion

Table 1 Significance of Characteristics in Explaining Price Variation in Cows sold at Auction in Rockhampton and Toowoomba - as indicated by the F-statistic

Variable(s)	Rockhampton	Toowoomba
Weight	2.14 [3]*	0.14 [3]
Fat	0.62 [3]	30.49 [5]***
Weight*Fat	2.19 [3]*	0.36 [4]
[All Weight, Fat]	1.28 [9]	10.43 [12]***
Muscle Score	5.47 [3]***	1.17 [3]
Muscle*Weight	4.72 [4]***	1.28 [3]
Muscle*Fat	0.94 [2]	3.03 [1]*
[All Muscle]	5.48 [9]***	2.22 [7]
Breed	3.36 [6]***	0.82 [6]
Origin	0.87 [3]	3.75 [3]*
Horns	0.23 [1]	1.10 [1]
Uniformity	3.77 [1]*	1.91 [1]
Number in Lot	0.85 [1]	5.57 [1]***
Sequence	3.46 [1]*	0.24 [1]
Auctioneer	3.50 [6]***	NR
RESET(2)	1.84	0.39
RESET(3)	2.83	2.28
RESET(4)	1.96	1.65
DW	2.05	2.00
R-squared (adjusted)	0.554 (0.469)	0.741 (0.678)
Sample Size	239	164

Number in bracket[ ] indicates number of regressors excluded
*** significant at 1% level
** significant at 5% level
* significant at 10% level

NR denotes that the variable was not recorded

Table 2 **Significance of Characteristics in Explaining Price Variation in Yearlings sold at Auction in Rockhampton and Toowoomba - as indicated by the F-statistic**

Variable(s)	Rockhampton	Toowoomba
Weight	0.30 [1]	2.14 [2]
Fat	0.04 [2]	3.07 [2]**
Weight*Fat	0.06 [2]	5.16 [3]***
[All Weight, Fat]	2.35 [5]*	5.57 [7]***
Muscle Score	1.81 [2]	0.49 [2]
Muscle*Weight	2.77 [3]**	4.19 [3]***
Muscle*Fat	1.62 [2]	1.82 [2]
[All Muscle]	3.53 [9]***	9.28 [7]***
Breed	1.26 [6]	3.03 [6]
Origin	0.69 [3]	9.53 [3]***
Horns	1.23 [1]	0.35 [1]
Uniformity	0.33 [1]	0.47 [1]
Number in Lot	3.68 [1]*	30.59 [1]***
Sequence	0.05 [1]	0.02 [1]
Auctioneer	2.12 [6]**	NR
Sex	2.10 [1]	1.83 [1]
RESET(2)	3.29	1.94
RESET(3)	2.24	2.13
RESET(4)	1.48	2.18
DW	2.13	1.87
R-squared (adjusted)	0.498 (0.302)	0.677 (0.639)
Sample Size	119	271

Number in bracket[ ] indicates number of regressors excluded
*** significant at 1% level
** significant at 5% level
* significant at 10% level

NR denotes that the variable was not recorded

Table 3 Significance of Characteristics in Explaining Price Variation in Steers sold at Auction in Rockhampton and Toowoomba - as indicated by the F-statistic

Variable(s)	Rockhampton	Toowoomba
Weight	12.66 [3]***	0.60 [3]
Fat	13.26 [3]***	3.63 [3]**
Weight*Fat	2.04 [4]*	0.24 [4]
[All Weight, Fat]	4.28 [10]***	2.13 [10]**
Muscle Score	0.22 [3]	9.52 [3]***
Muscle*Weight	0.20 [3]	6.59 [3]***
Muscle*Fat	1.07 [3]	2.25 [3]*
[All Muscle]	2.53 [9]***	15.01 [9]***
Breed	0.96 [6]	0.62 [6]
Origin	1.75 [3]	2.27 [3]*
Horns	0.05 [1]	16.53 [1]***
Uniformity	6.96 [1]***	0.07 [1]
Number in Lot	18.58 [1]***	3.90 [1]**
Sequence	1.12 [1]	5.44 [1]***
Auctioneer	0.61 [6]	NR
Feed	NR	7.26 [1]***
RESET(2)	12.01	3.79
RESET(3)	6.21	2.31
RESET(4)	4.12	1.53
DW	1.77	1.91
R-squared (adjusted)	0.757 (0.724)	0.762 (0.714
Sample Size	272	200

Number in bracket[ ] indicates number of regressors excluded
*** significant at 1% level
** significant at 5% level
* significant at 10% level

NR denotes that the variable was not recorded

Table 4 Significance of Characteristics in Explaining Price Variation in Heifers sold at Auction in Rockhampton and Toowoomba - as indicated by the F-statistic

Variable(s)	Rockhampton	Toowoomba
Weight	2.53 [1]	0.09 [1]
Fat	0.30 [2]	5.58 [3]***
Weight*Fat	2.49 [1]	0.44 [2]
[All Weight, Fat]	0.97 [4]	5.09 [6]***
Muscle Score	0.19 [2]	4.78 [2]**
Muscle*Weight	2.23 [3]*	2.65 [2]**
Muscle*Fat	1.15 [2]	0.46 [2]
[All Muscle]	5.02 [7]***	8.44 [6]***
Breed	0.79 [6]	0.78 [5]
Origin	1.34 [3]	7.17 [3]***
Horns	0.42 [1]	5.82 [1]***
Uniformity	2.41 [1]	3.25 [1]*
Number in Lot	1.48 [1]	0.60 [1]
Sequence	17.50 [1]***	16.42 [1]***
Auctioneer	2.62 [7]**	NR
Feed	NR	5.40 [1]**
RESET(2)	3.30	6.51
RESET(3)	1.61	11.02
RESET(4)	1.53	7.95
DW	1.84	1.51
R-squared (adjusted)	0.652 (0.543)	0.833 (0.790)
Sample Size	131	122

Number in bracket[ ] indicates number of regressors excluded
*** significant at 1% level
** significant at 5% level
* significant at 10% level

NR denotes that the variable was not recorded

Table 5 Estimated Model for Explaining the Price Variation In Cows sold at Auction in Rockhampton and Toowoomba (t-statistics shown in brackets)

Variable	Rockhampton	Toowoomba
Wt range 1	Used as base	Used as base
Wt range 2	-0.017 (-1.09)	0.029 (1.49)
Wt range 3	-0.013 (-0.79)	0.051 (2.43)***
Wt range 4	-0.006 (-0.26)	0.054 (2.38)***
Fat score 1	NR	-0.134 (-4.58)***
Fat score 2	-0.047 (3.19)***	-0.079 (-6.05)***
Fat score 3	Used as base	Used as base
Fat score 4	0.008 (0.61)	0.033 (2.46)***
Fat score 5	-0.016 (-0.52)	0.007 (0.37)
Fat score 6	NR	-0.207 (-7.87)***
Muscle B	Used as base	Used as base
Muscle C	-0.029 (-0.92)	0.074 (1.46)
Muscle D	-0.087 (-2.67)***	0.039 (0.76)
Muscle E	-0.111 (-3.06)***	0.001 (0.01)
Breed 1	0.018 (0.75)	-0.013 (-0.88)
Breed 2	-0.119 (-3.74)***	-0.077 (-2.31)**
Breed 3	-0.001 (-0.09)	0.099 (1.96)*
Breed 4	-0.002 (-0.14)	-0.013 (-0.78)
Breed 5	NR	0.035 (0.98)
Breed 6	-0.006 (-0.40)	NR
Breed 7	-0.036 (-1.41)	0.035 (1.13)
Breed 8	Used as base	Used as base
Origin 1	-0.012 (-0.62)	0.013 (1.06)
Origin 2	0.007 (0.50)	0.022 (1.20)
Origin 3	0.031 (1.70)*	0.056 (3.48)***
Horns	-0.005 (-0.43)	0.011 (-0.91)
Uniformity	0.029 (3.02)***	-0.017 (-1.55)
Number in lot	0.001 (0.91)	0.004 (2.61)***
Sequence	0.0004(2.36)***	0.000 (0.60)
Auctioneer 1	Used as base	NR
Auctioneer 2	0.040 (2.22)**	NR
Auctioneer 3	0.005 (0.25)	NR
Auctioneer 4	0.014 (0.68)	NR
Auctioneer 5	0.051 (2.61)***	NR
Auctioneer 6	0.057 (2.21)**	NR
Auctioneer 7	-0.004 (-0.23)	NR
Second sale	-0.068 (-5.15)***	NR
Constant	0.946 (23.37)***	0.873 (14.08)***
RESET (2)	1.68	0.01
RESET (3)	2.54	2.64
RESET (4)	1.75	1.82
DW	1.93	1.95
R-Squared	0.493 (0.423)	0.729 (0.682)
Sample size	239	164

Table 6 Estimated Model for Explaining the Price Variation In Yearlings sold at Auction in Rockhampton and Toowoomba (t-statistics shown in brackets)

Variable	Rockhampton	Toowoomba
Wt range 1	Used as base	Used as base
Wt range 2	0.001 (0.08)	0.011 (0.99)
Wt range 3	NR	0.028 (1.24)
Fat score 2	Used as base	Used as base
Fat score 3	0.036 (2.23)**	0.106 (8.28)***
Fat score 4	0.069 (1.53)	0.140 (5.68)***
Muscle B	NR	0.068 (5.36)***
Muscle C	Used as base	Used as base
Muscle D	-0.053 (-3.55)***	-0.054 (-3.74)***
Muscle E	-0.050 (-1.69)*	NR
Breed 1	-0.014 (-0.29)	0.009 (0.83)
Breed 2	0.055 (1.08)	0.013 (0.63)
Breed 3	0.040 (2.23)**	-0.105 (-3.30)***
Breed 4	-0.006 (-0.20)	0.020 (0.91)
Breed 5	NR	NR
Breed 6	0.012 (0.64)	-0.009 (-0.32)
Breed 7	0.071 (1.37)	-0.021 (-1.00)
Breed 8	Used as base	Used as base
Origin 1	-0.010 (-0.44)	-0.032 (-3.10)***
Origin 2	0.029 (1.30)	-0.012 (-0.75)
Origin 3	0.006 (0.22)	-0.007 (-0.29)
Horns	-0.020 (-0.71)	0.001 (0.08)
Uniformity	-0.017 (-1.16)	-0.009 (-0.69)
Number in lot	0.004 (2.49)***	0.006 (4.88)***
Sequence	-0.0001(-0.14)	-0.0003(-1.44)
Auctioneer 1	Used as base	NR
Auctioneer 2	0.024 (0.90)	NR
Auctioneer 3	-0.004 (-0.12)	NR
Auctioneer 4	0.027 (0.75)	NR
Auctioneer 5	-0.050 (-2.04)**	NR
Auctioneer 6	0.028 (0.89)	NR
Auctioneer 7	-0.017 (-0.49)	NR
Second sale	-0.029 (-1.64)*	NR
Sex	0.043 (1.50)	0.002 (0.11)
Constant	1.087 (21.70)***	1.188 (22.54)***
RESET (2)	6.21	8.28
RESET (3)	3.93	7.00
RESET (4)	2.88	5.16
DW	2.14	1.84
R-Squared (ajusted)	0.472 (0.265)	0.631 (0.601)
Sample size	119	271

Table 7 Estimated Model for Explaining the Price Variation In Steers sold at Auction in Rockhampton and Toowoomba (t-statistics shown in brackets)

Variable	Rockhampton	Toowoomba
Wt Range 1	Used as base	Used as base
Wt Range 2	0.047 (5.59)***	0.015 (0.92)
Wt Range 3	0.063 (5.91)***	0.005 (0.31)
Wt Range 4	0.082 (7.58)***	0.001 (0.08)
Fat score 2	Used as base	Used as base
Fat score 3	0.077 (5.34)***	0.090 (4.75)***
Fat score 4	0.116 (7.16)***	0.121 (5.32)***
Fat score 5	NR	0.076 (2.66)***
Muscle A	Used as base	Used as base
Muscle B	0.073 (2.15)**	-0.052 (-1.58)
Muscle C	0.040 (1.22)	-0.131 (-3.72)***
Muscle D	0.020 (0.62)	-0.222 (-5.80)***
Breed 1	-0.284 (-1.81)*	-0.013 (-0.87)
Breed 2	NR	-0.022 (-1.00)
Breed 3	NR	NR
Breed 4	0.012 (1.16)	0.005 (0.30)
Breed 5	NR	0.012 (0.32)
Breed 6	0.005 (0.66)	-0.008 (-0.30)
Breed 7	-0.018 (-1.18)	-0.002 (-0.07)
Origin 1	0.003 (0.27)	0.015 (1.13)
Origin 2	0.017 (1.68)*	-0.013 (-0.67)
Origin 3	0.011 (1.23)	0.020 (1.28)
Horns	-0.001 (-0.16)	-0.037 (-3.12)***
Uniformity	0.018 (2.66)***	-0.009 (-0.75)
Number in lot	0.003 (4.25)***	0.004 (2.85)***
Sequence	-0.0001(-1.25)	-0.0003(-1.45)
Auctioneer 1	Used as base	NR
Auctioneer 2	-0.003 (-0.27)	NR
Auctioneer 3	0.009 (0.62)	NR
Auctioneer 4	-0.008 (-0.56)	NR
Auctioneer 5	-0.025 (-1.58)	NR
Auctioneer 6	-0.001 (-0.04)	NR
Auctioneer 7	-0.005 (-0.39)	NR
Second sale	-0.018 (-2.30)**	NR
Feed	NR	0.069 (2.69)***
Constant	0.974 (30.73)***	1.290 (22.58)***
RESET (2)	12.00	4.12
RESET (3)	6.22	2.10
RESET (4)	4.13	1.70
DW	1.75	1.79
R-Squared (adjusted)	0.745 (0.718)	0.677 (0.634)
Sample size	272	200

Table 8 Estimated Model for Explaining the Price Variation In Heifers sold at Auction in Rockhampton and Toowoomba (t-statistics shown in brackets)

Variable	Rockhampton	Toowoomba
Wt range 1	Used as base	Used as Base
Wt range 2	-0.014 (-1.03)	0.005 (0.24)
Fat score 2	Used as base	Used as base
Fat score 3	0.076 (3.70)***	0.141 (5.89)***
Fat score 4	0.103 (4.35)***	0.174 (6.41)***
Fat score 5	NR	0.116 (3.83)***
Muscle B	Used as base	Used as Base
Muscle C	-0.057 (-2.72)***	-0.078 (-4.80)***
Muscle D	-0.103 (-4.46)***	-0.150 (-6.21)***
Breed 1	0.019 (0.80)	0.017 (0.93)
Breed 2	-0.025 (-0.69)	NR
Breed 3	0.021 (1.38)	0.018 (0.45)
Breed 4	0.010 (0.58)	0.012 (0.57)
Breed 5	0.036 (2.50)***	NR
Breed 6	NR	0.023 (0.68)
Breed 7	-0.007 (-0.21)	0.019 (0.84)
Breed 8	Used as base	Used as base
Origin 1	-0.023 (-1.04)	-0.043 (-2.30)**
Origin 2	-0.030 (-1.98)**	-0.023 (-1.06)
Origin 3	-0.028 (-1.37)	-0.092 (-4.60)***
Horns	0.006 (0.30)	-0.027 (-1.96)**
Uniformity	0.022 (1.86)*	0.033 (1.94)*
Number in lot	0.001 (0.65)	-0.003 (-1.38)
Sequence	-0.0015(-3.95)***	-0.0017(-5.01)***
Auctioneer 1	Used as base	NR
Auctioneer 2	-0.018 (-0.91)	NR
Auctioneer 3	-0.045 (-2.00)**	NR
Auctioneer 4	0.020 (0.68)	NR
Auctioneer 5	0.025 (1.27)	NR
Auctioneer 6	-0.010 (-0.32)	NR
Auctioneer 7	0.007 (0.24)	NR
Second sale	-0.061 (-4.32)***	NR
Feed	NR	0.110 (3.39)***
Constant	1.115 (26.42)***	1.240 (19.52)***
RESET (2)	3.11	5.96
RESET (3)	1.72	8.08
RESET (4)	1.53	8.82
DW	1.73	1.49
R-Squared (adjusted)	0.615 (0.523)	0.816 (0.781)
Sample size	131	122