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Muscle Score Premiums and Discounts in Wholesale Beef Carcases

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Abstract

There is an increasing emphasis in Australian beef industry R&D on finding ways to improve retail beef yield. Currently, there is no way to commercially measure retail yield but there is evidence of a strong link between muscle score of the live animal and subsequent meat yield measurements. A relevant question is whether there is a credible value for muscle score in live cattle and carcase markets, and does it reflect the implied value of increased retail yield? In this paper, estimates are made of the premiums and discounts for muscle score class at the Sydney wholesale market level. The results suggest premiums of 21 to 80c/kg for improvements from muscle score C/D to B. This can be compared with premiums of 18 to 45c/kg for improvements in one muscle score available in the Wagga Wagga saleyard market, and a premium of 16 c/kg for improvement in the assumed equivalent of one muscle score at the retail level. While there may be some debate about which is the "best" estimate, and the fact that the wholesale data ranges over more than one muscle score, it seems evident that premiums and discounts for muscle score evident in cattle saleyard prices and wholesale carcase prices appear to be over-estimates of the eventual increase in retail value.

Keywords: beef, wholesale market, hedonic models, muscle score, carcass characteristics

1. Introduction and Research Issue

There is an increasing emphasis in Australian beef industry R&D on finding ways to improve retail beef yield. Currently, there is no way to commercially measure retail yield but there is evidence of a strong link between muscle score of the live animal and subsequent meat yield measurements. A relevant question is whether there is a credible value for muscle score in live cattle and carcase markets, and does it reflect the implied value of increased retail yield?

In a recent analysis, Griffith *et al*. (2013) examined this question using reported weekly price data from the Wagga Wagga cattle saleyard market over the period July 2010 to June 2011. The data included prices for muscle score B, C and D steers (MSB, MSC and MSD, respectively), across a range of age, weight and fat score classes. In their preferred relative price model, they found a premium of around 12 per cent for a MSB carcase relative to a MSC carcase, all other attributes the same, or almost 25c/kg live weight (lwt) at the average reference class price. However, well muscled lighter animals are discounted

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by between 7 and 9 per cent or around 15c/kg lwt, so the net MSB premium for those classes is around 10c/kg lwt. They also found a 7 per cent discount for the lighter muscled animals, all other attributes the same, or around 14c/kg lwt. Further, yearlings that also have MSD are further discounted by over 6 per cent or almost 13c/kg lwt, and those animals that are both lightly muscled and have low fat cover are also discounted by some 6 per cent or 12c/kg lwt. The net MSD discount is therefore somewhat larger, near 27c/kg lwt, for those types of animals. Thus MSB animals have a premium of between 10 and 25c/kg, while MSD animals have a discount of between 14 and 27c/kg, on a live weight basis.

Given the strong biophysical relationship between muscle score, dressing percentage and retail beef yield (Perry *et al*. 1993a,b; Perry and McKiernan 1994; Café *et al*. 2006, 2012), a related question is whether the estimated c/kg premium for MSB relative to MSC (somewhere between 10 and 25c/kg lwt) relates closely or not to the estimated increase in carcase value due to an increase in retail beef yield? Based on quite limited data, Griffith *et al.* (2013) estimated the increased value of greater dressing percentage and retail yield of around 16c/kg on a carcase weight basis for an increase in one muscle score. Converting all values to carcase weight, this generates saleyard estimates of 18 to 45c/kg vs retail estimates of 16 c/kg. A conclusion drawn by Griffith *et al*. (2013) was that the premiums and discounts for muscle score evident in cattle saleyard prices appear to be over-estimates of the eventual increase in retail value.

While we cannot test this hypothesis directly due to lack of appropriate data at the retail level, we can test it at the wholesale level. Thus, this paper estimates the premiums and discounts for muscle score class at the Sydney wholesale market level, and assesses whether these are consistent with the estimates now available in the Wagga Wagga saleyard market.

2. Model and Data

The hedonic models used are the same as used in Griffith *et al*. (2013) and in several previous analyses of livestock markets in Australia and overseas (see for example Williams *et al*. 1993; Hufton *et al*. 2009). The details are provided in the appendix for interested readers. Two different forms of the model are specified and estimated, and then they are compared to see which form is the best representation of pricing behavior in the specified market. In the **absolute price model**, the estimated premiums and discounts for quality differences are constant - the differentials are independent of price levels, while in the **relative price model** the quality differentials are proportional to price - as prices rise the differentials expand, and as prices fall the differentials contract. In the saleyard market analysis reported in Griffith *et al*. (2013), the relative price model was preferred.

Price data from the Sydney wholesale market were obtained from the National Livestock Reporting Service (NLRS 2012) over the 47 week period from July 2010 to June 2011. Price data for only two quality characteristics were made available: five possible weight classes, and two possible muscle score classes. All classes were young beef and all had the same fat score FS 2/3. After the reference type was selected (180-200kg carcase weight, MSC/D), the total number of observations for estimation was n=423. Again, further details are available in the appendix.

3. Data Summary Statistics

The summary statistics for the final data set are given in Table 1. As expected, the reference price series (REF)[2] has a lower mean and less variability than the P_i series (PRICE), since the latter contains a wider range of carcase types. The ratio variable used in the relative price model therefore has a mean greater than one and quite high variability. The means of the dummy variables generally reflect the expected proportions of those characteristics in the final data sets, so the data set does not appear to be biased across any of the quality measures.

[2] All variable names are defined in the appendix.

Table 1. Data summary statistics

Number of Observations: 423				
	Mean	**Std Dev**	**Minimum**	**Maximum**
PRICE	443.70	44.50	335.00	540.00
REF	401.60	28.50	355.00	440.00
PRATIO	1.11	0.09	0.94	1.38
WT140	0.22	0.42	0.00	1.00
WT160	0.22	0.42	0.00	1.00
WT180	0.22	0.42	0.00	1.00
WT250	0.22	0.42	0.00	1.00
MSB	0.56	0.50	0.00	1.00

Figure 1. The reference price (180-200kg, MSC/D) and other wholesale prices at Sydney Homebush Market, 2010-2011

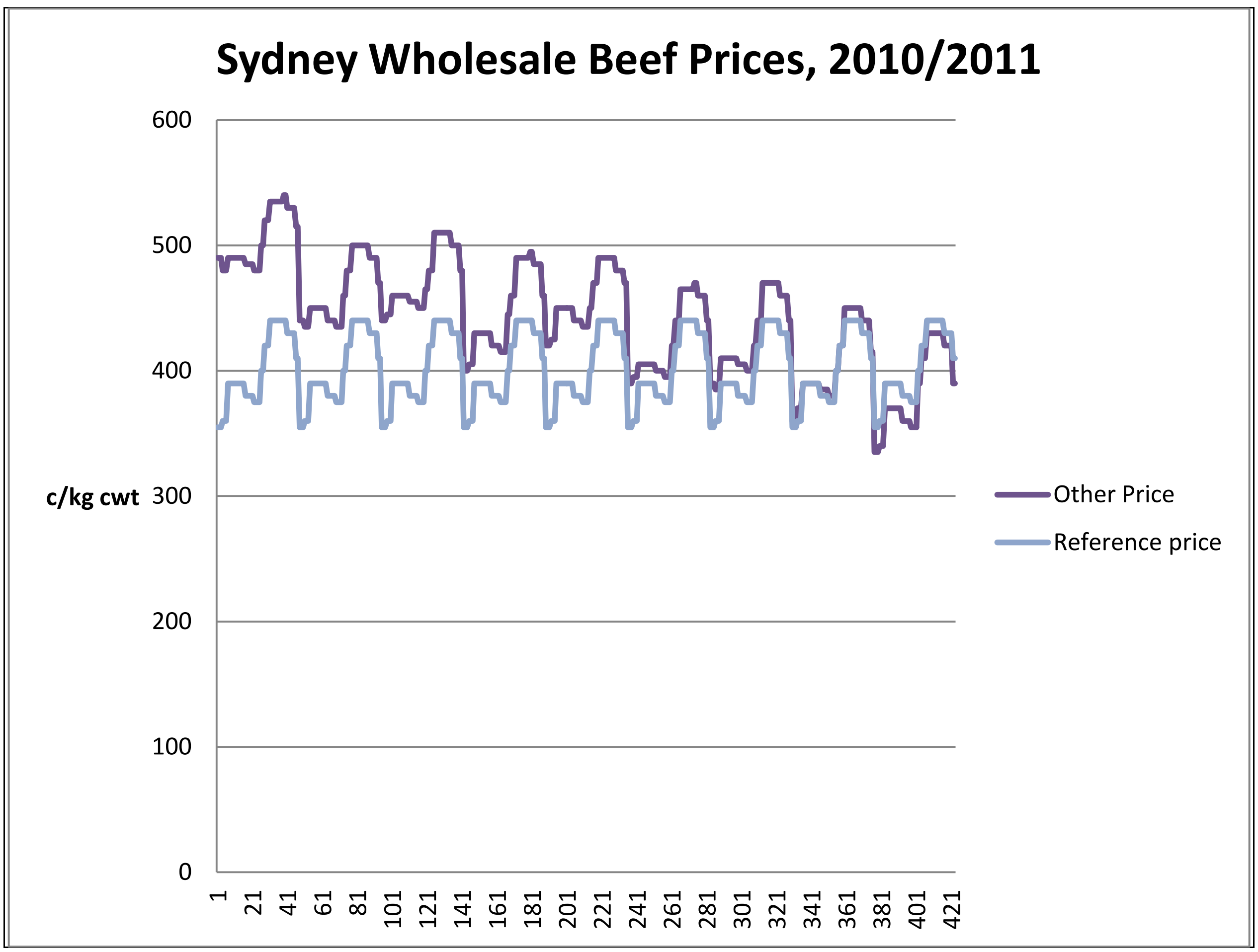

Figure 1 shows the relationship between the wholesale reference price and each of the other wholesale prices, sequentially over the nine sets of 47 weekly observations. The whole array of prices generally moves together in a broad seasonal pattern, but there is considerable short term variability in all prices.

It may be argued that calculated price differentials between some quality classes could also be explained by relatively small numbers of carcases offered for sale in these classes at any point in time. However, this seems unlikely in this data set given the relatively even balance across weight and muscle score classes. In Hufton *et al.* (2009) using saleyard lamb prices, yardings for each class were tested as an independent variable, but in no case was the yarding variable significant. Conversely, Griffith *et al.* (2013) found that yardings were significant in all versions of the Wagga Wagga saleyard models.

4. Results

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

- The base model was estimated that contained just the price terms and the characteristic dummy variables.
- Then, the base model was augmented sequentially with the set of seasonal dummy variables, with the set of characteristic interactions, and then with both sets, and F and Chi Square statistics were calculated to test for the inclusions.
- The preferred model was then subjected to specification tests including whether linear or log versions better fitted the data.
- The preferred absolute price and relative price models were then compared to see which model better fitted the data.

The Absolute Price Model

The summary data from each of the absolute price models and the test statistics for including the various sets of explanatory variables are shown in Table 2. Based on these results, the preferred model is the base model plus both the characteristic interaction terms and the seasonal dummy variables.

Table 2. Absolute price models

Model	**Adj. R^2**	**RESET2**	**Log Likelihood**	**F-statistic for inclusion**	**Chi Square statistic for inclusion**
Base Model	0.974	5.36*	-1433.97		
Base Model plus seasonality	0.979	38.12*	-1382.25	F(11,407)= 10.25*	CHI(11)= 103.43*
Base Model plus interactions	0.980	63.36*	-1372.95	F(4,413)= 34.53*	CHI(4)= 122.05*
Base Model plus seasonality plus interactions	0.986	251.63*	-1289.72	F(4,402)= 55.16*	CHI(4)= 185.08*
				F(11,402)= 17.62*	CHI(11)= 166.46*

Critical values at 5% are CHI(4)=9.488, CHI(11)=19.675, F(4,413)=2.39, F(11,407)=1.81.

* significant at 5%.

The preferred absolute price model therefore contains both seasonal effects and characteristic interactions. It is shown in Table 3.

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

Variable	Estimated Coefficient	Standard Error	t-statistic	P-value
REF	0.852	0.024	34.778	[.000]
WT140	117.049	9.297	12.590	[.000]
WT160	99.709	9.297	10.725	[.000]
WT180	78.113	9.297	8.402	[.000]
WT250	38.751	9.297	4.168	[.000]
MSB	80.347	9.297	8.642	[.000]
JAN	1.478	2.223	0.665	[.507]
FEB	2.865	1.801	1.590	[.113]
MAR	10.731	2.195	4.888	[.000]
APR	10.731	2.195	4.888	[.000]
MAY	11.510	2.055	5.602	[.000]
JUN	8.958	1.657	5.405	[.000]
JUL	6.854	1.571	4.363	[.000]
AUG	0.665	1.477	0.451	[.653]
SEP	-0.558	1.555	-0.359	[.720]
OCT	0.091	1.531	0.060	[.953]
NOV	0.444	1.462	0.304	[.762]
I1	-39.071	9.357	-4.174	[.000]
I2	-53.539	9.360	-5.720	[.000]
I3	-47.581	9.360	-5.084	[.000]
I4	-59.283	9.360	-6.334	[.000]

Adjusted R-squared = 0.986; Mean of dep. var. = 443.7; Durbin-Watson = 0.32 [<.000];

Ramsey's RESET2 = 251.6 [.000]

Here, almost 99 per cent of the variation in the price variable can be explained by the chosen variables. This indicates that at the wholesale level, differentiation between carcases is based primarily on end uses as predicted by carcase attributes and the other factors that influence price are less important. Further, as shown in Figure 1, the prices of the various characteristic classes move together. Based on the estimated coefficient of the reference price variable, a 10c/kg change in the reference price is reflected in an 8.5c/kg change in the prices of the other nine classes on average. Based on the estimated mean values of the two series, this equates to a price transmission elasticity of around 0.77.

All quality characteristics are highly significant. The four weight dummy variables are significant and positive and this means that if the weight class was to either decrease or increase from that of the reference class, there would be a significant premium from doing so of up to 117c/kg, at the reference muscle score. The coefficient for the MSB variable is also significant and positive, suggesting a premium of around 80c/kg for a MSB carcase relative to a MSC/D carcase, at the reference weight class.

However the data suggests some significant interactions between weight class and muscle score. If carcases are both lighter weight and MSB, the net premium is between 110c/kg and 157c/kg as weight decreases, while for carcases heavier than the reference class and MSB, the net premium is around 60c/kg.

Individually the monthly variables for March through to July have very significant coefficients suggesting premiums during these months relative to December (and the F and Chi-squared tests show that all seasonal variables should be included as a group). By selling in autumn and early winter, the vendor will receive a price premium of between 7 and 12c/kg.

The specification tests for functional form were inconclusive as shown in Table 4. The linear model was retained.

Table 4. Preferred absolute price model, specification tests

Absolute Price Model	**JA test**	**J test**
Ho: Linear is true	679.8* (reject)	323.4* (reject)
Ho: Log is true	-0.0056* (reject)	-0.0029* (reject)

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

The Relative Price Model

The relative price model was estimated using the same procedures as for the absolute price model. Again, based on the test statistics reported in Table 5, the preferred model included both seasonal effects and interactions between the weight and muscle score characteristics.

Table 5. Relative price models

Model	**Adj. R^2**	**RESET2**	**Log Likelihood**	**F-statistic for inclusion**	**Chi Square statistic for inclusion**
Base Model	0.924	43.56*	966.36		
Base Model plus seasonality	0.942	148.60*	1029.66	F(11,406)= 12.88*	CHI(11)= 126.59*
Base Model plus interactions	0.933	Very large*	995.32	F(3,414)= 20.25*	CHI(3)= 57.91*
Base Model plus seasonality plus interactions	0.952	203.59*	1069.73	F(3,403)= 28.02*	CHI(3)= 80.13*
				F(11,403)= 15.45*	CHI(11)= 148.82*

Critical values at 5% are CHI(3)=7.815, CHI(11)=19.675, F(3,403)=F(3,414)=2.62, F(11,406)=F(11,403)=1.81.

* significant at 5%.

The preferred relative price model is shown in Table 6.

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

Variable	Estimated Coefficient	Standard Error	t-statistic	P-value
C	1.015	0.007	150.135	[.000]
WT140	0.146	0.006	25.314	[.000]
WT160	0.101	0.006	17.542	[.000]
WT180	0.048	0.006	8.283	[.000]
WT250	-0.051	0.004	-12.625	[.000]
MSB	0.053	0.004	13.044	[.000]
JAN	-0.012	0.008	-1.537	[.125]
FEB	-0.018	0.006	-3.130	[.002]
MAR	-0.014	0.006	-2.340	[.017]
APR	-0.014	0.006	-2.400	[.017]
MAY	-0.008	0.006	-1.540	[.124]
JUN	0.003	0.006	0.525	[.600]
JUL	0.032	0.006	5.576	[.000]
AUG	-0.004	0.006	-0.696	[.487]
SEP	-0.011	0.006	-1.987	[.048]
OCT	-0.006	0.006	-1.120	[.263]
NOV	-0.001	0.006	-0.157	[.875]
I1	0.051	0.006	8.794	[.000]
I2	0.015	0.006	2.660	[.008]
I3	0.030	0.006	5.160	[.000]

Adjusted R-squared = 0.952; Mean of dep. var. = 1.106; Durbin-Watson = 0.44 [<.000];

Ramsey's RESET2 = 203.6 [.000]

As shown in Table 6, some 95 per cent of the variation in the ratio of P_i to the reference price is explained by the estimated model. All quality characteristics are individually highly significant. The four weight dummy variables are significant and this means that if the weight class was to decrease from that of the reference class, at the reference muscle score, there would be a significant premium from doing so of between 5 and 15 per cent. If the weight class was to increase from that of the reference class, at the reference muscle score, there would be a significant discount from doing so of about 5 per cent. The coefficient for the MSB variable is also significant and positive, suggesting a premium of around 5 per cent for a MSB carcase relative to a MSC/D carcase, at the reference weight class.

There are also some significant interactions between weight class and muscle score. Lighter carcases that also have MSB attract additional premiums of up to 5 per cent, so carcases of this type are awarded a premium of around 25 per cent if they are under 140kg, around 16 per cent if they are under 160kg and around 13 per cent is they are under 180kg. There is no significant interaction between weight class and muscle score for the under 250kg class.

The seasonal dummy variables are highly significant as a group but follow quite a different pattern as in the absolute price model. Individually the monthly variable for July suggests a strong premium of around 3 per cent, but all other significant coefficients suggest a discount away from the December base value.

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

Table 7. Preferred relative price model, specification tests

Relative Price Model	**JA test**	**J test**
Ho: Linear is true	-12.64* (reject)	1.170* (reject)
Ho: Log is true	9.604* (reject)	0.847* (reject)

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

Comparing the Absolute and Relative Price Models

Finally the preferred absolute and relative price models were tested against each other using J and JA tests. This involved transforming the preferred relative price model so that it had the same dependent variable as the preferred absolute price model. The results are shown in Table 8.

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

Absolute vs Relative Price Model	**JA test**	**J test**
Ho: Relative price model is true	2.440* (reject)	1.643* (reject)
Ho: Absolute price model is true	-1.421* (reject)	-1.427* (reject)

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

All four test statistics rejected the null hypothesis, so no one model dominates and the tests are inconclusive. Besides, the equation summary statistics are very similar. So while previous studies, especially Griffith *et al.* (2013), suggest that the relative price model provides a better explanation of premiums and discounts in saleyard auction prices due to carcass quality attributes, in this case both models are equally valid.

5. Summary and Conclusion

The key results are summarized in Table 9.

Table 9. The preferred relative price and absolute price wholesale beef carcase models, with interactions and seasonal effects

Variable	**Estimated coefficient from the preferred relative price model**	**Implied c/kg premium or discount at the mean reference price (401.6 c/kg)**	**C/kg premium or discount from the preferred absolute price model**
WT140 cf WT200, MSC/D	0.146	58.6	117.0
WT160 cf WT200, MSC/D	0.101	40.6	99.7
WT180 cf WT200, MSC/D	0.048	19.3	78.1
WT250 cf WT200, MSC/D	-0.051	-20.5	38.8
MSB cf MSC/D	0.053	21.3	80.3
WT140, MSB cf WT200, MSC/D	0.051	20.5	-39.1
WT160, MSB cf WT200, MSC/D	0.015	6.0	-53.5
WT180, MSB cf WT200, MSC/D	0.030	12.0	-47.6
WT250, MSB cf WT200, MSC/D			-59.3
Significant seasonal effects	Feb, March, April, Sept -0.01 to -0.02	-4.0 to -8.0	6.9 to 10.7
	July 0.03	12.0	

The results certainly indicate that different values do apply for different quality characteristics in the wholesale beef market, no matter which model is preferred. In the relative price model, premiums and discounts due to differences in weight in beef carcasses are evident, with very large premiums of almost 60c/kg for the very light 100-140kg carcases, smaller premiums of between 20 and 40c/kg for the 140-160kg and 160-180kg weight ranges, and discounts of over 20c/kg for the 220-250kg weight range, at the base C/D muscle score. The premiums for light weight carcases are further increased if the carcases also have a muscle score of B instead of C/D. There is a significant premium for MSB carcases over MSC/D carcases of more than 21c/kg, and this premium is increased if those carcases are also lighter than the reference class, up to 41c/kg for the lightest weight category.

In the absolute price model, the results indicate quite different levels of premiums and discounts for the weight and muscle score attributes and their interactions, with premiums and discounts at least twice as large as the relative price model, and up to four times as large for some effects. The premium for MSB ranges from 80c/kg for the reference weight class down to 26c/kg for the lighter weight classes.

Seasonal effects proved to be significant, but the pattern was quite irregular from month to month. In the relative price model, late summer, early autumn sales attracted a small discount, while mid winter sales showed a small premium. In the absolute price model, significant small positive premiums exist for March through to July.

In terms of carcase weight, we now have saleyard estimates of 18 to 45c/kg premiums for improvements in one muscle score, and wholesale estimates of 21 to 80c/kg premiums for improvements from muscle score C/D to B. The best retail estimate is a premium of 16 c/kg for improvement in one muscle score. While there may be some debate about which is the "best" estimate, and the fact that the wholesale data ranges over more than one muscle score, it seems evident that the conclusion drawn by Griffith *et al.* (2013) is confirmed: premiums and discounts for muscle score evident in cattle saleyard prices and and now evident in wholesale carcase prices appear to be over-estimates of the eventual increase in retail value. There must be other benefits to buyers from better muscled cattle than just more saleable meat.

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Appendix: Model and Data

Hedonic Models

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

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

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

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

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

where the variables are as defined above except that β is the mean value of the relative price ratio, and the error term is different. The hypothesis here is that the quality differentials are proportional to price - as prices rise the differentials expand, and as prices fall the differentials contract.

These two specifications are tested against each other using non-nested tests reviewed by Doran (1993).

Data

A number of specific data choices have to be made to implement the various models:

* **Selection of market**. The NLRS only reports on the Sydney wholesale market. Reports are provided each week.

* **Selection of NLRS beef carcase quality characteristics**. The NLRS reports contain a variety of information with the aim of providing accurate information regarding the market. Reports generally contain the following information: Fat score, Muscle score, Category weight, Age and Cents per kg (low, high and average).

From this list only two quality characteristics were made available by the NLRS. These were carcass weight (5 possible classes – 100-140 kg, 140-160 kg, 160-180 kg, 180-200 kg, and 200-250 kg) and muscle score (2 possible classes – MS C/D and MS B). All classes were young beef and all had the same fat score FS 2/3. Other factors known to influence price were excluded because the variables are not reported by the NLRS.

* **Selection of beef carcase types. P**rice data were made available for 10 different beef carcase types (5 weight classes each with 2 muscle scores).

* **Selection of reference type.** One of these types has to be chosen as the reference type. Based on discussions with NLRS staff and examination of sale numbers for each type, the reference type selected was 180-200 kg MS C/D beef carcases.

* **Selection of time period.** To obtain price series which covered different seasons and different market conditions, the time period selected was from 1 July 2010 to 30 June 2011. This resulted in a maximum number of 47 weekly sale observations for each of the carcase types. There were no missing values, so the total number of observations is therefore n=10*47=470.

Final Wholesale Model

For each of the 9 non-reference beef carcase types, the price series for that type (P_i) and the reference price series (P_r) were entered as continuous series and the series for the quality characteristics were entered as dummy variables, where the dummy took the value zero if it was identical to the reference type and one if it was different. Thus there were five dummy variables for quality characteristics (wt140, wt160, wt180, wt250, msb). The data set was then organised in panel format with the possible 47 observations on each of the 9 (non-reference) beef carcase types stacked vertically. This gave an estimation sample of 423 observations. Eleven monthly dummy variables were constructed and added to account for variations in pasture growth patterns, cattle breeding cycles and seasonality in demand for different types of meat, both domestically and in export markets. Interaction terms between the quality characteristics were constructed and added, as were interaction terms between the seasonal variables and the quality characteristics.

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

(3) P_i = f (P_r, wt140, wt160, wt180, wt250, msb, monthly seasonal dummies (11), characteristic interactions (4), seasonal/characteristic interactions (55)), and

(4) P_i/P_r = f (Constant, wt140, wt160, wt180, wt250, msb, monthly seasonal dummies (11), characteristic interactions (4), seasonal/characteristic interactions (55)).

The characteristic interactions were defined as I1 = wt140*msb; I2 = wt160*msb; I3 = wt180*msb; and I4 = wt250*msb.

Due to potential degrees of freedom problems, the seasonal/characteristic interactions were ignored in all future analyses.