# The Influence of Fat and Weight on the Price of Lamb in the Homebush Livestock and Wholesale Markets

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An econometric analysis is reported of the relationship between price, and fat cover and weight, in the Homebush livestock and wholesale markets in 1987, 1988 and 1989 using data from the Livestock Market Reporting Service. Implicit prices for changes in weight and fat cover were estimated while accounting for changes in supply and demand conditions for lamb. The analysis lends support to the view that consumer preference for leaner lamb was not being reflected in prices offered for lamb in traditional auction markets.

## 1. Introduction

The objective of the analysis reported in this paper was to establish the contribution of variations in fat cover and carcase weight to variations in the price of lamb in the Homebush livestock auction and wholesale markets. The study was motivated by three issues.

First, as Waugh pointed out in the first empirical study of the relationship between price and quality (discussed in Berndt), analysis of the contribution of quality factors to price variation 'may prove to be fully as useful as the studies of factors causing the general level of prices to change from day to day or from season to season' (Waugh, p.187), because a producer has greater control over these factors than over general market conditions. The findings of this study are of particular relevance to producers who market their lambs through livestock auctions.

Second, there is concern in the lamb industry that there is a divergence between the values placed by consumers on fat cover and portion size, and the implicit prices received by producers for these quality factors in live lamb auction markets. Such price divergence raises the question of whether efficiency gains in the lamb industry can be made by the development of weight and grade selling systems where attributes such as weight and fat cover are explicitly valued and price divergence reduced. By estimating these implicit prices in auction and wholesale markets, this study will contribute to establishing the extent of any price divergence.

A final issue motivating this study was that the analysis should provide insights about whether the weight and fat classes used in the Livestock Market Reporting Service (LMRS) are based on changes in the levels of these factors that would cause lamb buyers operating in auction markets to alter their marginal implicit valuations of these factors. If these classes are useful then significant price differentials should be observed between classes.

## 2. Evidence of Price Divergence

Most lamb carcases sold on the domestic market weigh about 17kg (AMLC, p.7) with a fat score of 3 to 4 (PDP Australia, p.5), where a fat score of 1 is very lean and that of 5 is very fat. Casual observation in the Homebush livestock markets suggests that fat score 4 lambs received a premium (in cents per kg carcase weight) over fat score 3 lambs, which in turn received a premium over fat score 2 lambs. A price discount for excessive fat cover only applied to fat score 5 lambs. Price differentials for weight (or size) were difficult to discern. In the wholesale market the fat score 3 lambs seemed to command a premium.

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While there have been several empirical studies of price-quality relationships in the Australian beef industry, which are reviewed in Williams, Rolfe and Longworth, only one similar analysis of the Australian lamb industry has been undertaken. From an analysis of lamb prices in Victoria, West (p.7) found significant variation in the relationship between price and fat cover and weight through time and perhaps, between selling centres, and cautiously concluded that 'there is some reason to believe that best prices are paid for lambs with fat scores and carcase weights in the middle of the range and that fat scores and carcase weights on either side receive less'.

There have been a number of studies of the attitudes of Australian consumers to the attributes of lamb (Thatcher and Couchman; Kingston; Hopkins and Congram; Hopkins, Congram and Shorthose). The latter (p.18) conclude that: "more than 75 per cent of consumers favoured cuts from carcases which had a 'GR' fat measurement of between 6 and 10mm (Fat Score 2) and weighed more that 20kg (Weight Class X)".

However, a major weakness of these attitudinal studies is that they do not attempt to measure the value placed by consumers on the product attributes in question. To overcome this problem, Mullen and Wohlgenant used a contingent valuation approach to value changes in two important attributes of lamb loin chops - fat cover and area of red meat. When lamb chops from a 17kg carcase, fat score 2, were valued at $5.50 per kg, the expected discount for a fat score 3 chop with the same area of red meat was $2.29 per kg, a factor of about one half. Therefore there is a willingness by consumers to pay more for lean lamb. Mullen and Wohlgenant were not able to identify a significant price premium for chops with an area of red meat larger than presently provided by lamb carcases of 17kg.

This brief review of the literature supports the widely held view in the industry that price divergence between the retail, wholesale and auction markets exists. Two implications flow from a divergence at different market levels in the implicit prices of attributes such as fat cover and weight. First, the existence of such a divergence suggests that there may be gross benefits to the industry from developing a system of weight and grade or description selling. The size of the benefits would be related to the extent of the price divergence. Second, producers should link production decisions about weight and fat cover with the decision about whether the lambs are to be sold through an auction market or through a system in which the implicit prices of attributes are more closely related to consumer valuations of these attributes. How important these implications are depends on the extent of the price divergence. Measuring price differentials for fat cover and weight in the livestock and wholesale markets contributes to establishing the extent of this price divergence.

## 3. Data

Most lambs in New South Wales (NSW) are sold through livestock auction markets on a per head basis after being drafted into pens which should be uniform for characteristics of economic significance to buyers. These characteristics include age, weight, fat cover and value of skin. Buyers visually assess these characteristics and bid in an auction setting accordingly. The number of lambs in a pen varies.

In NSW, the Meat Industry Authority operates the LMRS which reports sales at major centres[1]. The objective of these reports is to provide information to producers and processors about the supply of lambs; about the general level of prices; and about price differentials for different types of lamb.

The market reporter assesses the average dressed weight of the lambs in the pen and after deducting an estimate of the value of the skins, quotes an estimated dressed weight price in cents per kilogram. Price quotations are also made on a cents per kg liveweight basis and a per head basis and for skins. The market reporter assesses the average fat score of the pen on a scale of 1 to 5. Fat cover is estimated as the depth of soft tissue at the 12th rib, 110mm from the carcase midline (the GR site). The five classes for fat score are <5mm; 5-10mm; 10-15mm; 15-20mm and >20mm. Until October 1987, lambs were classified on a dressed weight basis into three weight classes: <16kg; 16-19kg; and >19kg, which are referred to below as weight classes 1 to 3. After that date four weight classes, referred to below as 4-7, were used: <16kg; 16-18kg; 18-20kg; and >20kg. Lambs are also classified as to whether they are new season lambs (suckers) or weaned lambs. Lambs have no permanent incisor teeth.

[1] The LMRS operates in a very similar manner in all States.

At the conclusion of the sale, a report is issued which contains average price quotations for all weight and fat classes for which there were sufficient pens to form a reliable quotation. There are many weight and fat combinations for which a market quotation is not made[2].

The LMRS also reports the wholesale market, formerly at Homebush but now at the Sydney Meat Hall, Strathfield, in which lamb carcases are sold. In the wholesale market, lambs are traded by private treaty and hence the market report is based on the cooperation of wholesalers in divulging prices that they receive for different types of lamb. The fat classes are the same as in the livestock market but weight class 1 lambs are less than 16.5kg, class 2 lambs are 16.6-18.5kg, class 3 lambs are 18.6-20kg and class 4 lambs weigh more than 20kg. No distinction is made between young and old lambs in the wholesale market reports.

Data were taken from the daily reports of the sheep market at the Homebush livestock markets issued by the LMRS. Sheep and lamb sales were held at Homebush on Tuesdays and Thursdays. The data cover the period from January 1987, when the LMRS started reporting the lamb wholesale market on a weight and fat class basis, until February 1989[3]. The wholesale market was reported on Wednesdays over the same period. It remained active after the livestock market closed before transferring to the Sydney Meat Hall, and hence the data through to August 1989 were used[4].

As mentioned above, price quotes were not available for all classes of lamb on all sale days. For example, young lambs were never available in Autumn. There were only six observations in the livestock market for fat score 1 lambs over the whole data period and one of these appeared to have been mis-reported. These observations were discarded.

The price data from individual sale days were transformed into monthly average prices to smooth out some of the day-to-day price variation[5]. For the livestock auction data, there were 121 observations for various weight class and fat class combinations for the period from January 1987 until October 1987 and 244 observations for the period from October 1987 until February 1989. For the wholesale data there were 421 observations from January 1987 until August 1989.

There are important differences in the nature of the data used in this study from that used in the beef industry studies reviewed in Williams *et al.* In the beef studies, the researchers collected observations on price and quality attributes (of which the LMRS attributes were only a subset) for all individual pens at a small number of sales held in a short period of time. In this study data from LMRS market reports were used which meant that there was only one observation for each class of lamb at any one sale and no observations for those classes not offered for sale that day (or for which there were less than three pens sold) but the data extended over two years.

## 4. Hedonic Price Analysis

Hedonic price analysis is often used to analyse price-quality relationships. In this framework, reviewed in Berndt, products such as lamb can be viewed as consisting of heterogeneous bundles of a number of characteristics or attributes that are of economic significance. These heterogeneous bundles are often referred to as grades or classes. The implicit marginal values of these attributes can be derived from an hedonic price equation in which product price is regressed on the quantities of attributes.

Two hypotheses were examined concerning the relationship between the implicit prices of attributes such as fat cover and weight, and the general price level of lamb. The first hypothesis is that the implicit prices are constants and independent of the general price level. This hypothesis, referred to here as the absolute price model, underlies the model used by Williams *et al.* (1993) which took the form:

[2] Market reports issued by the LMRS are widely published, especially in the rural press, and often disseminated by electronic means.

[3] Data were available until August 1989 when the livestock market was closed. However because the numbers of lambs sold fell markedly throughout 1989, these data were not used.

[4] The wholesale analysis was conducted over the same period as the livestock market analysis and over the longer more recent period reported in the paper. There was very little difference and the longer and more recent data series was used because the need for strict comparability was not that great for the purposes of this paper.

[5] Monthly prices have been used in studies in similar areas such as the analysis of marketing margins in livestock industries (Griffith, Green and Duff).

(1) $P_i = P_r + \Sigma X_{ij}p_j$

where $P_i$ is the price of a particular class of lamb; $P_r$ is the price of a reference weight and fat class of lamb; $X_{ij}$ is the quantity of attribute j, fat cover or weight for example, supplied by class i; and the $p_j$ terms, the coefficients estimated in the regression, are the price differentials from the reference class of lamb for a unit change in attribute j.

The second hypothesis referred to as the relative price hypothesis, is based on Waugh's pioneering work and takes the form:

(2) $P_i / P_r = \alpha + \Sigma X_{ij}p_j$.

In this model, implicit prices for attributes are proportional to the general price level for lamb[6] rather than constants as in the absolute price model[7]. This hypothesis seems to be supported by a subjective assessment of LMRS reports which suggests that price differentials for fat and weight classes do vary with the general price level. An attraction of this model is that it removes the problems of simultaneity bias associated with having $P_r$ as an explanatory variable.

These alternative hypotheses about the behaviour of implicit prices for attributes are not nested within each other. The J and JA tests described in Doran for testing alternative nonnested hypotheses were used below. The principle in nonnested testing is to introduce into each of the competing models a variable which contains information from the alternative. If the augmenting variable is significant, as measured by a t-statistic, then the alternative model contains information which is not being captured by the maintained model. An attraction of testing alternative hypotheses over the use of general specification tests such as the RESET test is that additional data based on an alternative theory are being applied to the question. However, nonnested testing requires that the dependent variables for the competing hypotheses be the same, which is not the case for equations 1 and 2. Hence the Waugh model, equation 2, was transformed in the following way[8]:

(3) $P_i = \alpha P_r + \Sigma X_{ij}p_jP_r$.

Equation 3, referred to below as the transformed Waugh model, was used solely for nonnested testing against the absolute price model. Equation 2 was the general form used to estimate implicit prices under the relative price hypothesis in the event that the relative price model was preferred to the absolute price model. Although the evidence was not conclusive, nonnested testing generally favoured the relative price model and hence the specific models discussed below are expressed in relative price terms.

An important difference between the present study and that by Williams, Rolfe and Longworth concerns the role of the reference price and the nature of the data. Clearly the price of lamb is influenced by general supply and demand conditions common to all grades of the product. In the lamb industry, the seasonal nature of production also results in price variation, a large component of which is likely to be common to all grades. Because the Williams *et al.* study was conducted over a short time period using prices of many individual sale lots, it is highly likely that there was little variation in these general supply and demand conditions and hence no need for them to explicitly account for this source of price variation. They interpreted their estimated intercept as the price of the reference lot of cattle.

In this study, a time series over two years of average monthly prices for different classes of lamb was used. It is most likely that general supply and demand conditions for lamb varied over this time. To account for this source of price variation, Waugh's approach was followed of normalising the price series by the price of a reference class of lamb, $P_r$. This process of normalisation should also account for seasonal variations in demand and supply that are common to all grades of lamb. In the livestock market, the reference grade was the weight class 2, fat score 4 grade from January until October 1987. From November 1987 until February 1989, it was the weight class 5, fat score 4 grade. In the wholesale market, it was the weight class 2, fat score 4 grade throughout the period. These grades were most plentiful in supply throughout year and hence should reflect general market trends most reliably. In estimating models (1) and (3), the price of the reference class was included as an explanatory variable.

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[6] As can be seen more clearly in a variant of this model, equation 3.

[7] The concept of relative and absolute price differentials is similar to the concept of relative and absolute price spreads developed in Wohlgenant and Mullen.

[8] If the variance of the error term in equation 3 was related to the reference price, then the relative price model has the added attraction of reducing heteroscedasticity.

In these specifications the implicit prices of attributes represented by the $p_j$ coefficients are constant relative to each other, only changing in response to factors common to all grades. However they can be thought of as resulting from the interaction of the demand for and supply of particular levels of attributes which may vary through time. Berndt, (p.117) in reviewing hedonic price analyses of industrial goods such as cars and computers, argued that 'in empirical implementations, particular care should be given to checking whether the parameters of hedonic price equations are stable over time'. In the lamb industry the supply of weight and fat attributes is likely to vary seasonally in response to regular seasonal patterns in ewe fertility and feed availability. The supply of these attributes is also going to vary in response to unexpected climatic variability. This issue of the variability of implicit prices, both through time and relative to each other, has received little attention in past hedonic analyses of livestock prices in Australia. No doubt this has been due to the short time period over which such analyses have been conducted.

In this study also, there were not enough observations to identify seasonal effects with any confidence. To check whether the estimated relative price differentials were influenced by supply and demand conditions in particular seasons over the observation period, interaction terms between season and the weight and fat attributes were introduced[9].

There are a number of alternative ways of expressing the fat, weight and age classes. Some (O'Connell) seem to have used the raw class scores for fat and weight. In other studies (Waugh; Ladd and Suvannunt; and Ladd and Martin), the attributes were measured as continuous variables. In both approaches quadratic terms for the explanatory variables were introduced to allow the implicit price to change as the quantity of the attribute changed.

The approach adopted here was to express the weight and fat classes as dummy variables (as did Williams *et al.*) Age (lamb and young lamb) was also expressed as a dummy variable. This approach had a number of attractions[10]. First, it allowed price differentials for weight and fat scores on either side of the reference class to vary both in size and sign. Hence it allowed the price differential in moving to fat score 5 to be negative and the price differential in moving to fat score 3 to be positive. Second, because weight and fat cover are classified according to the LMRS system, it allowed an explicit analysis of the appropriateness of the LMRS classes. If the LMRS does efficiently discriminate between lambs that differ in economic value then the price differentials associated with each weight and fat score were expected to be significant. Third, the approach allowed an examination of whether there was interaction between weight and fat cover such that at higher weights, the penalty against fat was reduced, for example[11].

The final issue is that of functional form. Williams *et al.* used linear models and Cropper, Deck and McConnell, after pointing out that theory provided little guidance in the choice of functional form in reduced form hedonic price models, found that linear models performed well against alternative functional forms. Ladd and Suvannunt noted that many hedonic pricing models use double log or semilog specifications[12]. They preferred linear specifications because they were consistent with their hypothesis that the price of a product was the sum of the products of the marginal yields of product characteristics and the implicit prices of these characteristics. That approach is followed here, although in the Waugh models implicit prices are proportional to $P_r$. In the case of lamb, the price of lamb is hypothesised to be the sum of the level of fat cover by the implicit price of fat and the weight of the lamb by the implicit price of weight. A RESET test (Thursby), in which the linear models were augmented by second, third and fourth powers of the fitted values of the dependent variable from the linear model, was applied as a specification test[13].

[9] An alternative approach would have been to introduce interaction terms for each month of the data series to identify abnormal months.

[10] A Waugh model in which fat and weight were expressed as continuous variables was estimated but the dummy variable models were preferred on statistical grounds and for the reasons noted below concerning their specification.

[11] It was found that the effects of age were adequately captured by an intercept dummy variable and that interaction effects between age and fat and weight class did not add to the explanatory power of the models.

[12] The immediate practical objection to log models is that it is not possible to take the logs of dummy variables whose value is one.

[13] The null hypothesis that the linear model was an acceptable specification was not rejected if there was no significant change in the value of the likelihood function when the augmenting variables were introduced.

## 5. Livestock Auction Models

As noted above, the number of weight classes used in LMRS reports increased from three to four in October 1987. There was no obvious way of pooling the data from these two periods and separate models for each period were estimated. The base models which follow the Waugh specification, were:

(4) $P = \alpha + \delta_2 F2 + \delta_3 F3 + \delta_5 F5 + \theta_1 W1 + \theta_3 W3 + \varepsilon L$, and

(5) $P = \beta + \lambda_2 F2 + \lambda_3 F3 + \lambda_5 F5 + \rho_4 W4 + \rho_6 W6 + \rho_7 W7 + \sigma L$.

where P is monthly average price of lamb in cents per kg dressed weight normalised by the price of the reference grade. A dummy variable for young lamb, as distinct from lamb, is represented by L and dummy variables for fat and weight classes are represented by F and W[14]. To avoid a singular matrix, and hence allow estimation of all coefficients, the dummy variables for the reference weight and fat classes were dropped. In addition the few observations for fat score 1 lambs were discarded and hence this dummy variable was also omitted.

Two other scenarios were examined. In the first of these, interaction terms between fat and weight scores were added to allow the price differential for fat to depend on weight class and vice versa. This was done in response to views such as heavier lambs being able to 'carry' more fat before suffering a price penalty. In the third scenario, interaction between season and fat cover and weight, as well as weight/fat interactions, was accommodated. The likelihood ratio testing procedure was used to assess whether these two groups of interaction terms made significant contributions to the explanatory power of the models. The test statistic is (the negative of) twice the difference of the log likelihood values of the restricted and unrestricted models. The null hypothesis that the interaction terms do not contribute to explanatory power is not rejected if the test statistic is less than the critical $\chi^2$ value at the 5 percent level where the degrees of freedom is the number of interaction terms.

When the coefficients for these models (equations 4 and 5) are multiplied by the average price for the appropriate reference grade lambs - fat score 4, weight class 2 (\$1.50/kg) or 5 (\$1.37/kg), they can be interpreted as price differentials associated with changes in weight, fat and age at the average price of the reference grade lambs. The intercept terms become the average prices for the reference grade lambs (or close approximations). The $\delta$ and $\lambda$ terms are the price differentials associated with a change in fat score for the reference grade of lamb. The $\theta$ and $\rho$ terms are the price differentials associated with a change in weight class for fat score 4 lambs. The $\varepsilon$ and $\sigma$ terms are the price differentials associated with young lamb as distinct from lamb for the reference grade lambs.

Thus, the price differential at the average price of the reference lamb for a young fat score 2, weight class 4 lamb is given by $(\lambda_2 + \rho_4 + \sigma)$*\$1.37.

## 6. Wholesale Model

The absolute and relative price specifications were also compared for the wholesale market. A dummy variable model was used which took the form:

(6) $P = \phi + \eta_1 F1 + \eta_2 F2 + \eta_3 F3 + \eta_5 F5 + \mu_1 W1 + \mu_3 W3 + \mu_4 W4$,

where, for the Waugh model, prices were normalised by the price of fat score 4 weight class 2 lambs.

## 7. Livestock Auction Results

The estimation procedure involved estimating models (1), (2) and (3) for each of the three scenarios and two observation periods to allow nonnested testing of the relative and absolute price models (using models 1 and 3), to allow the significance of interaction terms to be assessed, and to allow some judgement to be made about the adequacy of the linear functional form, using the RESET test. The results from this procedure are presented in Tables 1 and 2.

Unexpectedly, fat/weight interactions did not significantly add to the explanatory power of any of the models for either time period using a likelihood ratio test. The test statistics, degrees of freedom and critical $\chi^2$ values used in conducting these tests for the Waugh model are presented in Table 1[15]. Whether seasonal interaction effects enhanced the models is

[14] The use and interpretation of dummy variable models is well presented in Kmenta.

[15] There is enough information in Tables 1 and 2 for the reader to conduct similar tests for the absolute price model.

**Table 1: Degrees of Freedom and $\chi^2$ for Significance of Interaction Terms in Waugh Models**

| **Livestock Market:** | Nov. 1987 - Feb. 1989 | | | Jan. - Oct. 1987 | | |
|---|---|---|---|---|---|---|
| Interaction | Test Stat | D's of F | $\chi^2$ (5%) | Test Stat | D's of F | $\chi^2$ (5%) |
| Weight/Fat | 6 | 7 | 14.07 | 2 | 4 | 9.49 |
| Seasonal | 20 | 18 | 28.87 | 24 | 13 | 22.36 |

| **Wholesale Market:** | Jan. 1987 - Aug. 1989 | | |
|---|---|---|---|
| | Test Stat | D's of F | $\chi^2$ (5%) |
| Weight/Fat | 26 | 10 | 18.31 |
| Seasonal | 84 | 21 | 32.67 |

Test Statistic: Twice the difference of the log likelihood values of the restricted and unrestricted models.
D's of F: Degrees of freedom - number of restricted coefficients
$\chi^2$ (5%): The critical value of $\chi^2$ at the five percent level

**Table 2: Specification Tests for Livestock Auction Models**

| | Log L'hood Values | J -test (t-stat) | JA -test (t-stat) | RESET $H_0$ |
|---|---|---|---|---|
| **Nov. 1987 - Feb. 1989** | | | | |
| *No interaction terms:* | | | | |
| Waugh Model | 266 | | | not reject |
| Transformed Waugh Model | -908 | 1.79 | 1.42 | reject |
| Absolute Price Model | -911 | 3.0 | 2.14 | reject |
| *Weight - Fat interaction terms:* | | | | |
| Waugh Model | 269 | | | not reject |
| Transformed Waugh Model | -903 | 1.62 | 1.14 | reject |
| Absolute Price Model | -908 | 3.63 | 2.36 | reject |
| *Seasonal interaction terms:* | | | | |
| Waugh Model | 279 | | | reject |
| Transformed Waugh Model | -892 | 2.48 | 1.97 | reject |
| Absolute Price Model | -889 | 1.08 | 0.32 | reject |
| **Jan. - Oct. 1987** | | | | |
| *No interaction terms* | | | | |
| Waugh Model | 138 | | | reject |
| Transformed Waugh Model | -463 | -0.58 | 0.87 | reject |
| Absolute Price Model | -468 | 2.67 | -2.28 | reject |
| *Weight - Fat Interactions* | | | | |
| Waugh Model | 139 | | | reject |
| Transformed Waugh Model | -461 | -0.53 | 0.97 | reject |
| Absolute Price Model | -467 | 2.78 | -2.18 | reject |
| *Seasonal Interaction Terms* | | | | |
| Waugh Model | 151 | | | reject |
| Transformed Waugh Model | -447 | -1.32 | 2.12 | reject |
| Absolute Price Model | -454 | 3.71 | -2.80 | reject |

debatable. They enhanced the absolute and the transformed Waugh models but in the case of the Waugh model, the null hypothesis that seasonal interaction terms did not increase the model's explanatory power cannot be rejected for the longer and most recent observation period, November 1987 to February 1989, and was barely rejected at the five percent level for the earlier period. The Waugh and transformed Waugh models behaved differently in this respect. This was unexpected and perhaps can be explained by the possibility of a simultaneity problem arising from having the reference price as an explanatory variable in the transformed Waugh model.

For the models with either no interaction terms or with weight/fat interaction terms, both the J and JA tests suggested that the transformed Waugh model and hence the Waugh model, were preferred to the absolute price model[16]. However when seasonal interaction terms were included the picture was less clear. For the most recent observation period, the absolute price model was preferred to the transformed Waugh model, although barely in the case of the JA test. For the earlier observation period, the absolute price model remained unsatisfactory but, for the JA test at least, the transformed Waugh model was also unsatisfactory.

Faced with this conflicting evidence, the Waugh model with no interaction terms was preferred. This preference was based on the model's simplicity, the absence of possible simultaneity problems and the fact that it was one of few models to meet the RESET test. The Waugh models with weight/fat interaction terms had similar qualities to models with no interaction terms, but with less explanatory power.

The results for the Waugh models with no interaction terms, for the two observation periods are presented in Tables 3 and 4. Both models have good statistical properties. Almost all coefficients are statistically significant. The $R^2$ for the models were 0.63 and 0.60[17]. Standard errors were estimated using the approach suggested by White for heteroscedastic-consistent estimates.

The direction of the price differentials was consistent with expectations for livestock auction markets such as Homebush. Buyers discounted changes in fat cover in either direction from fat score 4 as evidenced by the negative signs on all fat score dummy variables. The differentials were reasonably similar in both periods although the discount for fat score 5 lambs was almost twice as large in the earlier period. The discount for being overfat tended to be smaller than for being too lean.

**Table 3: Waugh Model for Livestock Market: Nov. 1987 - Feb. 1989**

| | Co-efficient | t-statistic | Average Price Differential (c/kg) |
|---|---|---|---|
| Intercept | 0.98 | 87.80 | 141.3 |
| Fat 2 | -0.23 | -10.40 | -33.9 |
| Fat 3 | -0.11 | -7.79 | -15.7 |
| Fat 5 | -0.09 | -6.17 | -12.8 |
| Weight 4 | 0.03 | 1.62 | 3.6 |
| Weight 6 | -0.04 | -2.55 | -5.9 |
| Weight 7 | -0.13 | -8.49 | -18.3 |
| Young Lamb | 0.11 | 10.20 | 16.4 |
| Log Likelihood | 266 | $R^2$ | 0.60 |

**Table 4: Waugh Model for Livestock Market: Jan. - Oct. 1987**

| | Co-efficient | t-statistic | Average Price Differential (c/kg) |
|---|---|---|---|
| Intercept | 0.98 | 87.40 | 147.4 |
| Fat 2 | -0.26 | -8.62 | -39.6 |
| Fat 3 | -0.11 | -8.02 | -17.0 |
| Fat 5 | -0.16 | -6.42 | -24.5 |
| Weight 1 | -0.02 | -1.07 | -2.6 |
| Weight 3 | -0.05 | -3.00 | -6.8 |
| Young Lamb | 0.08 | 4.82 | 12.0 |
| Log Likelihood | 138 | $R^2$ | 0.63 |

The picture with respect to weight differentials was not quite so clear cut. In both periods the lighter weight classes (1 and 4) were not significantly different from the base weight classes and a move to a heavier weight was discounted. This was surprising since, although there is little evidence that consumers

[16] From Table 2, in the transformed Waugh models the augmenting variables which contain information from the absolute price models, do not add to the explanatory power of these models, as evidenced by low t -statistics, whereas the reverse holds for the absolute price models.

[17] Both models had low Durbin-Watson statistics but as we are not estimating traditional time series models not much importance was placed on this test and no adjustments were made.

are prepared to pay a premium for larger cuts of lamb (Mullen and Wohlgenant), killing charges are levied on a per head rather than a weight basis.

As expected, young lamb attracted an average premium of about fourteen cents per kg relative to lamb. Interaction terms between age and either fat score or weight class made little contribution to the explanatory power of either model.

Because econometric support for the simple Waugh model was ambiguous, the absolute price model for the most recent observation period with weight/fat and seasonal interaction terms is presented in Table 5. In theory at least, the price discount for a fat score 3 weight class 7 lamb in winter is 24.9 c/kg (-11.3-17.7+8.9-7.0+2.2) but as Williams *et al.* warn, such a literal interpretation should be avoided. The problem with the price differentials from the simple Waugh models is that they may be biased because important explanatory variables, in this case the interaction terms, have been omitted. The problem with the full absolute model is that most of the interaction effects are insignificant. This may arise from the expected high degree of collinearity between many of the explanatory variables which is likely to result in imprecise estimates of the price differentials. However for this data set there was little change in the explanatory power of the models when interaction terms were introduced, hence multicollinearity may not be a severe problem.

With this qualification in mind, the full model supports the observations made from the simple Waugh model although the coefficients for individual weight and fat classes are smaller[18]. The significant coefficient on the fat 3, weight 7 interaction term is some evidence that lambs that are both leaner and heavier than the reference class, fat 4 weight 5, were not discounted as heavily as lambs that were only leaner or only heavier, but the other interaction terms did not support this view.

The interaction terms between winter and all fat classes were all negative and significant. Recall that there are not enough observations to conclude that this is a regular feature of the winter lamb market. These results would seem to say that fat score 4 lambs were in short supply during the winter of 1988.

[18] Note that the coefficients in the absolute models are the price differentials.

**Table 5: Absolute Model with all Interactions: Nov. 87-Feb.89 - Livestock**

| | Coefficient | t-stat | | Coefficient | t-stat |
|---|---|---|---|---|---|
| Intercept | 1.0 | 85.2 | summer*F2 | -8.1 | -1.2 |
| Fat 2 | -29.5 | -3.3 | summer*F3 | -3.5 | -1.0 |
| Fat 3 | -11.3 | -4.0 | summer*F5 | 0.4 | 0.1 |
| Fat 5 | -9.0 | -2.1 | autumn*F2 | -11.8 | -1.5 |
| Weight 4 | 3.1 | 1.1 | autumn*F3 | -3.0 | -0.9 |
| Weight 6 | -3.0 | -0.8 | autumn*F5 | 2.9 | 0.7 |
| Weight 7 | -17.7 | -7.5 | winter*F2 | -26.9 | -3.1 |
| Age | 14.2 | 9.8 | winter*F3 | -7.0 | -2.0 |
| F2*W4 | 8.2 | 0.9 | winter*F5 | -14.2 | -3.2 |
| F3*W4 | -1.0 | -0.3 | summer*W4 | -0.2 | -0.1 |
| F3*W6 | 2.4 | 0.5 | summer*W6 | -3.3 | -0.9 |
| F3*W7 | 8.9 | 2.2 | summer*W7 | 4.5 | 1.6 |
| F5*W4 | 6.4 | 1.2 | autumn*W4 | 4.0 | 1.0 |
| F5*W6 | 0.2 | 0.0 | autumn*W6 | -5.8 | -1.6 |
| F5*W7 | -1.8 | -0.4 | autumn*W7 | -3.4 | -1.1 |
| | | | winter*W4 | 4.9 | 1.3 |
| Log Likelihood | | -889 | winter*W6 | -6.2 | -1.3 |
| $R^2$ | | 0.88 | winter*W7 | 2.2 | 0.5 |

**Table 6: Specification Tests for Wholesale Models**

| | Log L'hood Values | J -test (t-stat) | JA -test (t-stat) | RESET $H_o$ |
|---|---|---|---|---|
| **Jan. 1987 - Aug. 1989** | | | | |
| *No interaction terms:* | | | | |
| Waugh Model | 532 | | | reject |
| Transformed Waugh Model | -1670 | 12.5 | 9.16 | reject |
| Absolute Price Model | -1640 | -5.46 | -7.60 | reject |
| *Weight - Fat interaction terms:* | | | | |
| Waugh Model | 545 | | | not reject |
| Relative Price Model | -1660 | 18.50 | 12.60 | reject |
| Transformed Waugh Model | -1610 | -8.16 | -9.71 | reject |
| *Seasonal interaction terms:* | | | | |
| Waugh Model | 587 | | | not reject |
| Transformed Waugh Model | -1620 | 15.80 | 12.3 | reject |
| Absolute Price Model | -1580 | -8.64 | -10.9 | reject |

## 8. Wholesale Results

A similar estimation procedure was followed for the wholesale market. The results of the various specification tests are presented in Tables 1 and 6. In the wholesale market, both the weight/fat and the seasonal interaction terms added significantly to the explanatory power of the models. In addition, the nonnested testing of the absolute and relative price models suggested that neither model satisfactorily captured the behaviour of the implicit prices of attributes in this market, with or without interaction terms. However, at this stage a more satisfactory specification is not apparent.

The results for the Waugh model with weight/fat and seasonal interaction terms included, are presented in Table 7. The attraction of the Waugh model was that the seasonal and weight/fat interaction specifications passed the RESET test and the simple specification only just failed this test. Imprecise estimation of the coefficients in this model, because of multicollinearity, is likely to be a more significant problem because both sets of interaction terms add to the model's explanatory power.

Of the main weight and fat attributes, only the coefficient for weight class 3 was not significantly different from zero. The $R^2$ was 0.74.

Ignoring the interaction terms initially, it would seem that in the wholesale market, unlike the livestock market, there was a premium for lambs with fat scores of less than 4. There was a clear preference for fat score 3 lambs but fat score 1 and 2 lambs were both preferred to fat score 4 lambs. However the behaviour of both markets with respect to weight appears to be similar. In particular there appears to be a significant premium for weight class 1 lambs over weight class 2 lambs. Note that at the wholesale level the lambs are in carcase form and hence the incentive arising from per head killing charges to pay more for heavier lambs, no longer applies.

Turning to the weight/fat interaction terms[19], it would seem that the initial premium for weight class 1 lambs was offset to some degree if the lambs were also lean. A premium for the fat score 5 weight class 4 lambs also supports the view that heavier lambs can also carry more fat without attracting a discount. The seasonal effects seem to be saying that for the years over which this model was estimated there was a shortage of lighter leaner lambs in Spring. However while most interaction effects would appear to reduce the premiums for fat score 3 and weight class 1 lambs, they would not be eliminated.

[19] And bearing in mind earlier comments about the need for caution in interpreting price differentials in the presence of multicollinearity.

**Table 7: Waugh Model for Wholesale Market: Jan. 87 - Aug. 89**

| | Co-efficient | t-statistic | Average Price Differential (c/kg) |
|---|---|---|---|
| Intercept | 1.00 | 1640.00 | 194.0 |
| Fat1 | 0.01 | 13.60 | 1.6 |
| Fat2 | 0.07 | 4.45 | 12.8 |
| Fat3 | 0.24 | 10.80 | 46.7 |
| Fat5 | -0.15 | -13.20 | -29.7 |
| Weight1 | 0.09 | 4.95 | 17.7 |
| Weight3 | -0.00 | -0.02 | -0.1 |
| Weight4 | -0.07 | -3.80 | -14.2 |
| F1*W1 | -0.04 | -1.72 | -8.5 |
| F1*W3 | 0.03 | 1.00 | 4.8 |
| F2*W1 | -0.04 | -2.02 | -7.1 |
| F2*W3 | 0.01 | 0.70 | 2.1 |
| F2*W4 | 0.05 | 1.92 | 9.6 |
| F3*W1 | -0.04 | -1.90 | -8.3 |
| F3*W3 | -0.03 | -1.61 | -6.2 |
| F3*W4 | -0.03 | -1.27 | -5.5 |
| F5*W3 | -0.01 | -0.89 | -2.7 |
| F5*W4 | 0.07 | 3.64 | 13.4 |
| summer*F1 | -0.13 | -4.48 | -25.3 |
| autumn*F1 | -0.14 | -6.45 | -27.4 |
| winter*F1 | -0.02 | -1.48 | -3.4 |
| summer*F2 | -0.00 | -0.10 | -0.4 |
| autumn*F2 | -0.00 | -0.00 | -0.0 |
| winter*F2 | -0.03 | -1.98 | -6.4 |
| summer*F3 | -0.06 | -2.01 | -10.7 |
| autumn*F3 | -0.07 | -3.37 | -14.2 |
| winter*F3 | -0.08 | -3.50 | -15.3 |
| summer*F5 | 0.02 | 1.13 | 4.7 |
| autumn*F5 | 0.00 | 0.10 | 0.4 |
| winter*F5 | 0.04 | 2.37 | 7.7 |
| summer*W1 | -0.04 | -1.55 | -8.0 |
| autumn*W1 | -0.07 | -3.30 | -14.0 |
| winter*W1 | -0.06 | -2.74 | -11.4 |
| summer*W3 | -0.02 | -1.16 | -4.5 |
| autumn*W3 | -0.02 | -1.11 | -3.8 |
| winter*W3 | -0.02 | -1.15 | -3.8 |
| summer*W4 | -0.01 | -0.44 | -2.3 |
| autumn*W4 | -0.04 | -1.82 | -7.6 |
| winter*W4 | -0.02 | -0.97 | -4.4 |
| Log likelihood | 587 | $R^2$ | 0.74 |

# 9. Discussion and Conclusions

The analysis above confirmed widely held views in the industry about price differentials for fat cover that exist in livestock auction and wholesale markets for lamb. Price premiums were paid for fat score 4 lambs in the auction market and for fat score 3 lambs in the wholesale market. Industry views about the price differentials existing for weight were less clearly stated but there was general consensus that premiums should be paid for heavier lambs because of savings in processing costs and because of attitudinal studies which suggested that consumers would prefer larger cuts of lamb. However, in both the livestock and wholesale market it was found that for fat score 4 lambs, an increase in weight attracted a discount. There was some limited evidence that a shift towards lambs that were both leaner and larger would attract a premium or at least, be discounted less.

This divergence in the way wholesale and livestock markets value fat cover means that producers should link production decisions about weight and fat cover with the decision about whether the lambs are to be sold through an auction market or through a system in which the implicit prices of attributes are more closely related to consumer valuations of these attributes.

The analysis was less successful in determining the extent to which implicit prices for attributes were influenced by the general price level for lamb; by weight/fat interactions; and by seasonal factors. There was some evidence that price differentials in the livestock market were directly related to the general price level or, more technically, that the relative price specification can be preferred to the absolute price specification. Both specifications appeared to be inadequate for the wholesale market.

Despite the fact that the empirical testing did not provide clearcut results in this case, the methodology developed in this paper is a more general approach to analyzing price/quality relationships than has been applied to Australian livestock industries in the past. Moreover the regression techniques used are no more complex than those used in previous studies.

Unexpectedly there was no strong evidence that in the livestock market price differentials for fat cover depended on weight class and vice versa. Weight/fat interactions seemed to be more important in the wholesale market. There was stronger evidence, particularly in the wholesale market, that price differentials respond to changes in the supply and demand for attributes. Supply conditions are expected to be the greatest source of variation but not enough data were available to identify a regular seasonal pattern, as distinct from a random pattern, to these changes in price differentials. This adds another dimension to the way in which expectations about weather or season should influence production decisions.

The analysis raises a number of points for discussion. First, the analysis clearly confirms that buyers discriminate between lambs that differ in fat cover and weight. Additionally the system of weight and fat classes used in the LMRS in both the livestock and wholesale markets does reflect differences in economic value to buyers in these markets. Freebairn argued that these were necessary conditions for benefits to be gained from a uniform grading system.

Second, in addition to the divergence observed in this study between price differentials for fat cover in the livestock and wholesale markets, there is a divergence between these markets and perceived consumer preferences for leaner and perhaps larger lamb. Some of the more nebulous characteristics of traditional livestock auction markets said to contribute to this divergence, are that they are 'conservative', 'inefficient', 'lack competition', 'transmit price signals poorly'. The existence of a price divergence is often used as evidence of market inefficiencies and the introduction of a grid or description selling system is proffered as a remedy to these problems.

It may be more helpful to recognise that these two selling systems provide different services with respect to the transfer of information and risk and this may explain divergences in how fat and weight are valued. In auction markets where buyers purchase pens of lambs with varying and uncertain weight and fat cover, it may be prudent to buy fatter, lighter lambs to meet consumer requirements for tenderness, knowing that excess fat can be trimmed. In a grid selling system more of the risk and management skill is transferred to the producer. The fact that these divergences exist suggests that there are potential gross benefits to the industry from encouraging trading on a description basis. The benefits arise in part because the proposed system would allow some buyers and sellers of lambs to alter the risk bearing and information gathering functions that they undertake. The Meat Research Corporation is currently providing financial support to this end.

Finally, one of the arguments for establishing LMRS's across Australia was that the data collected would allow analyses such as that reported here. As Waugh pointed out in 1928, quantitative analyses of the contribution of product attributes such as fat cover and weight are likely to be just as relevant to farmer's production decisions as analyses of price variation from general supply and demand conditions. Despite this, very few such analyses have been conducted either of livestock markets or of grain or horticultural markets. This study has examined some of the methodological issues likely to be encountered in such analyses.

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