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# QUARTERLY ESTIMATES OF THE DEMAND AND PRICE STRUCTURE FOR MEAT IN NEW SOUTH WALES

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**Multiple regression estimates of demand and price relationships for fresh beef, lamb and mutton in the N.S.W. livestock auction, wholesale, and retail markets during the period from January 1951 to June 1963 are presented. The results show that direct price elasticities of demand were negative, and of greatest absolute value in the retail market. Mutton is shown to have been a close substitute for beef and lamb, but the latter were not close substitutes with respect to price.**

## *Introduction*

### *Meat Market Structure*

The livestock auction, wholesale, and retail markets for meat in N.S.W. are clearly distinguishable as separate, though closely related, identities.

The auction market for livestock destined for slaughter as human food comprises a large number of separate sub-markets located in most of the cities and rural areas of the state. These can be regarded as parts of the aggregate state-wide livestock market because prices paid at each centre, apart from normal local variation due to short-run supply factors, are dependent on the prices paid by buyers at the Flemington (Sydney) saleyards. This relationship may have been weakened over the period studied by the decentralizing effects of the establishment of large regional abattoirs in rural areas. Data which may have revealed the quantitative effects of decentralization were not available to the author, so no valid check on these effects could be made.

The wholesale meat market is limited to the major cities and large country towns, where the volume of the meat trade is such that there is a need for the organizational and distributional activities of wholesale firms. The quantity of meat which passed through the wholesale market during the study period was that purchased by buyers for resale as fresh meat in the domestic market. The remainder of production either entered the meat processing trade or was exported.

The retail market for fresh meat in N.S.W. is characterized by a large number of retail stores, a high proportion of which are located in the Sydney metropolitan area. Despite the large number of retail butchers' shops, the retail market for meat is probably not very competitive because of consumer loyalty, and because knowledge on the part of both retailers and consumers is far from perfect.

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*Consumption Pattern for Beef, Lamb, and Mutton<sup>1</sup>*

Estimates of meat consumption in N.S.W. indicate that during the period studied, the quarterly mean total consumption of carcass meat per head of population was 48·8 pounds and the means for beef, lamb and mutton were 28·3, 9·0, and 11·5 pounds respectively.<sup>2</sup> The greater variation in the consumption of the individual meats compared to that of the "total" figure suggests that consumers tended to maintain a stable total meat consumption by substitution among the meats in response to changes in market conditions.<sup>3</sup> An examination of the interrelationships between the meats is therefore warranted.

*Previous Studies of the Demand for Meat in Australia*

Meat marketing has been a neglected field of study in Australia. To date, only three studies of the demand for meat, all based on annual data, have been made public.

Taylor examined the retail demand for beef during the period from 1949-50 to 1959-60.<sup>4</sup> In a later study, he widened the scope of his original work to include mutton and lamb.<sup>5</sup> The third study was carried out by van der Meulen, who studied the retail demand for beef, lamb and mutton during the period from 1949-50 to 1961-62.<sup>6</sup> These three papers therefore covered almost the same ground, and all suffered from the disadvantage of being based on a small number of observations, which necessarily reduced the reliability and usefulness of the estimates. Also, in his earlier study, Taylor presented regression residuals which were subject to significant autocorrelation.<sup>7</sup> This tends to throw doubt on the validity of the estimates presented in the three papers by Taylor and van der Meulen, because all three were closely similar in scope and method.

*The Models*

Each of the three markets is represented by a model, and these are connected by equations which specify the determinants of the margins between the prices in each market.

<sup>1</sup> Consumption of each meat was estimated as the residual of total production minus exports, canning, and change in stocks held. As there were no available data relating directly to consumption, errors in the above data were unavoidably transferred to the consumption estimates.

<sup>2</sup> The "beef" figures used in this study were actually an aggregate of beef plus veal. This was necessary because the data on exports, canning and change in stocks were available only in aggregate form.

<sup>3</sup> The coefficients of variation for the total, and individual consumption figures for meat were: total, 5·5; beef, 14·8; lamb, 25·6; mutton, 12·2.

<sup>4</sup> G. W. Taylor, "Beef Consumption in Australia", *Quarterly Review of Agricultural Economics*, Vol. XIV, No. 3 (July 1961), pp. 128-137.

<sup>5</sup> G. W. Taylor, "Meat Consumption in Australia", *Economic Record*, Vol. 39, No. 85 (March 1963), pp. 81-87.

<sup>6</sup> J. van der Meulen, "Demand for Meat on the Retail Level". A paper presented to the September 1963 meeting of the Australian Agricultural Economics Society in Sydney.

<sup>7</sup> The test for autocorrelation used was that suggested by H. Theil and A. L. Nagar, "Testing the Independence of Regression Disturbances", *Journal of the American Statistical Association*, Vol. 56 (December 1961), pp. 793-806. The value of the test statistic (1·21) was significant at the 0·05 level.

*Livestock Auction Market*

The structural model is composed of three price functions and three demand functions as follow:

- (1)  $P_{Ba} = f(S_B, S_S, P_{Be})$
- (2)  $P_{La} = f(S_L, S_B, S_M, P_{Le})$
- (3)  $P_{Ma} = f(S_M, S_B, S_L, P_{Me})$
- (4)  $C_B = f(P_{Ba}, P_{La}, P_{Ma})$
- (5)  $C_L = f(P_{La}, P_{Ba}, P_{Ma})$
- (6)  $C_M = f(P_{Ma}, P_{Ba}, P_{La})$

where  $P$  = price in pence per pound of carcass meat (deflated by the Consumer Price Index);

$S$  = supply (quantity slaughtered) in pounds per head of population;

$C$  = consumption in pounds of carcass meat per head of population;

$B, L, M, S$  as subscripts = beef, lamb, mutton and sheepmeats, respectively;

$a$  = auction market;

$e$  = export market.

Supply of each of the meats was assumed to be independent of current price, and thus entered the price functions as a predetermined variable, because:

(a) The numbers of livestock potentially available for slaughter in any given period were determined at the time of mating. The degree to which this potential was realized depended on seasonal conditions during pregnancy and at the time of birth, and on mortality rates during the growth period.

(b) Expectations with regard to price and seasonal conditions were likely to have been more important factors than current price in marketing decisions, because of the lag period necessary for fattening following the decision to market stock.

(c) Although, in the very short term, it is possible for producers to vary supplies to the market in response to current price, it is generally impracticable to hold prime stock for periods greater than a few weeks, or to fatten stock very rapidly. Therefore, during any given quarterly period, the total supply forthcoming was unlikely to have been significantly influenced by current price.

Due to the importance of export markets as outlets for a part of N.S.W. production, export prices were included as explanatory variables in the price functions.<sup>8</sup> Since most meat exported was sold on contract, export prices were known to buyers several weeks prior to shipping, and were used as a guide by buyers of animals destined for the export market. Due to the competitive nature of the livestock auction market, the known export prices thus influenced the auction price. Unfor-

<sup>8</sup> In 1951, the proportion of N.S.W. production of each meat exported was: beef, 0.4 per cent; lamb, 1.4 per cent; mutton, 1.1 per cent. In 1962, the proportions were: beef, 28.1 per cent; lamb, 1.6 per cent; mutton, 10.6 per cent. The increases for beef and mutton were largely attributable to the growth in the U.S. market for these meats.

tunately the export price series for mutton and lamb was available only as an aggregate for both meats. Satisfactory export prices could not be calculated from any available data, so these prices were excluded from the estimating equations.

Supply of sheepmeats (mutton plus lamb) was used as an explanatory variable in the beef price function because mutton and lamb probably acted as complementary substitutes for beef, the former replacing the lower grades of beef, and the latter the higher grades.

#### *Wholesale Market*

Since the activities of meat wholesalers are concentrated in certain areas, variables entering the wholesale model should have included only the meat handled in these areas. As these data were not available, it was assumed that consumption per head in areas served by wholesalers was not significantly different from that in other areas, and per caput consumption data for the whole state were used.

The auction-to-wholesale margins were considered to consist of two components; the first related to marketing costs, the second to the profit objectives of the wholesale firms. The largest cost item in wholesale marketing is undoubtedly the cost of labour, which was best measured by the wage rates payable to employees. The profit component, dependent on the decisions of individual firms, was difficult to relate to available data. The auction price was probably a determinant of profit, and the volume of consumption was probably also important, so these variables entered the margin functions, which follow:

$$(7) \quad M_{Bw} = f(P_{Ba}, C_B, W_m, W_w, C_L, C_M)$$

$$(8) \quad M_{Lw} = f(P_{La}, C_L, W_m, W_w, C_B, C_M)$$

$$(9) \quad M_{Mw} = f(P_{Ma}, C_M, W_m, W_w, C_B, C_L)$$

where  $M_w$  = the auction-to-wholesale margin per pound;

$B, L, M$  as subscripts = beef, lamb, mutton;

$W_m$  = the wage rate payable in food manufacturing;

$W_w$  = the wage rate payable in the wholesale and retail trade.

The calculated margins were the difference between the deflated wholesale and auction prices, and were consequently in real terms. The wage rates were also deflated by the Consumer Price Index. Due to the high correlation between the two wage rates ( $r = 0.99$ ), the variable  $W_w$  was not included in the statistical equations.

#### *Retail Market*

Retail prices were the sum of the livestock auction prices and the margins set by wholesale and retail firms, and were thus exogenously determined. The retail consumption of each meat was expressed as a function of its retail price, the prices of competing meats, and the disposable income of consumers.

The functions representing the margins between the wholesale and retail prices were as follow:

$$(10) \quad M_{Br} = f(P_{Bw}, C_B, W_r, C_L, C_M)$$

$$(11) \quad M_{Lr} = f(P_{Lw}, C_L, W_r, C_B, C_M)$$

$$(12) \quad M_{Mr} = f(P_{Mw}, C_M, W_r, C_B, C_L)$$

where  $M_r$  = the wholesale-to-retail margin, in pence per pound (real terms);

$W_r$  = the wage rate payable to employees in retail stores, deflated by the Consumer Price Index.

The demand functions for the retail market were:

$$(13) \quad C_{Br} = f(P_{Br}, P_{Lr}, P_{Mr}, Y)$$

$$(14) \quad C_{Mr} = f(P_{Mr}, P_{Br}, P_{Lr}, Y)$$

$$(15) \quad C_{Lr} = f(P_{Lr}, P_{Br}, P_{Mr}, Y)$$

where  $C_r$  = retail consumption per head of population;

$P_r$  = deflated retail price in pence per pound of carcase meat;

$Y$  = deflated non-farm personal disposable income per head.

There were no available data relating to the quantities of each meat entering the institutional trade (schools, hospitals, gaols, restaurants), so the total N.S.W. consumption per head was used as an approximation to retail consumption.<sup>9</sup>

For the period from the December quarter, 1954, to the June quarter, 1960, the retail price series for lamb was non-existent. Accordingly, this period could not be included in the estimating equations in which the retail price of lamb was a variable. Therefore the retail demand equations for beef and mutton were estimated twice: once for the entire period (March 1951 to June 1963), with lamb price excluded, i.e. equations (13a) and (14a); and once for the period for which lamb prices were available, with this variable included, i.e. equations (13b) and (14b).<sup>10</sup>

Initial examination of all items of data revealed that the time series were subject to seasonal variation, which could have contributed to autocorrelation in the regression residuals. All data series were therefore deseasonalized using a centered four-quarter moving average.<sup>11</sup> This resulted in the loss of four observations from each of the data series, thereby reducing the maximum number of available observations to 46. In the retail demand equations, this maximum was further reduced by four because the data necessary for calculation of personal non-farm disposable income could be obtained only up to the June quarter, 1962. The lamb retail price series was reduced by eight observations, leaving a maximum of 19 usable observations, because the series was deseasonalized in two sections to take account of the large gap in the data.

It was necessary to use two equations for estimation of the retail demand function for lamb because when the full equation was estimated, with explanatory variables as set out in function (15) above, the variance-covariance matrix approached singularity. This was probably due to the high correlation between the lamb and mutton prices

<sup>9</sup> It seemed likely that meals eaten in the various institutions simply replaced meals at home, so that the total per caput consumption in N.S.W. should not have differed from actual retail per caput consumption.

<sup>10</sup> See Table 4.

<sup>11</sup> A disadvantage of this procedure is that it introduces an oscillatory variation in the data series. This is the Slutsky-Yule Effect, and is discussed in M. G. Kendall, *Advanced Theory of Statistics* (London: Griffin, 1946), p. 381. However, this effect was almost certainly less damaging to the estimates than the autocorrelation due to seasonality. See Appendix for sources of data used.

( $r = 0.81$ ) and the price of beef and personal non-farm disposable income ( $r = 0.75$ ). The equations used appear in Table 4, as numbers (15a) and (15b).

#### *Estimation Procedure*

The functional relationships developed above were estimated by single-equation least squares procedures. This method was used, despite the apparent simultaneity of the relationships, because of the statistical problems introduced by the presence of autocorrelated residuals in the estimated equations. Johnston has pointed out that when this problem is encountered, there is no theoretical evidence on which to base the choice between simultaneous-equation estimators and ordinary least squares.<sup>12</sup> The choice must therefore be made for reasons other than the theoretical properties of the estimators.

The ordinary least squares method lends itself to modification by a procedure, suggested by Cochrane and Orcutt, which recovers most of the efficiency lost as a result of the autocorrelation.<sup>13</sup> This procedure depends on knowledge of the autoregressive scheme of the residuals and is not applicable to simultaneous-equation estimators because little is known of the effects of autocorrelated residuals in simultaneous models.<sup>14</sup>

The residuals of all equations fitted were tested for autocorrelation using the test proposed by Theil and Nagar.<sup>15</sup> The test statistic, based on the von Neumann ratio of mean successive difference to the variance of the residuals, is given by:

$$Q = \frac{\sum (\mu_t - \mu_{t-1})^2}{\sum \mu_t^2}$$

where the  $\mu_t$  are estimated residuals, and the subscripts have the usual significance with respect to time. Theil and Nagar have tabulated precise significance limits for their test statistic.

The procedure suggested by Cochrane and Orcutt involved the transformation of the original data in each equation according to the autoregressive scheme followed by the residuals. Determination of this was made by fitting a third-order difference equation, of the form

$$\mu_t = \alpha\mu_{t-1} + \beta\mu_{t-2} + \gamma\mu_{t-3} + \eta_t,$$

by ordinary least squares.

The significance of the coefficients was determined by the  $t$  test, and significant autoregression coefficients were used to transform the original data. The transformed equations, of the form

$$(Y_t - \alpha Y_{t-1}) = \alpha' + \sum_{i=1}^n b_i'(X_{i,t} - \alpha X_{i,t-1}) + e_t$$

were re-estimated using least squares.<sup>16</sup> Testing of the residuals from

<sup>12</sup> J. Johnston, *Econometric Methods* (New York: McGraw-Hill, 1960), pp. 294, 295.

<sup>13</sup> D. Cochrane and G. H. Orcutt, "Application of Least-Squares Regression to Relationships Containing Autocorrelated Error Terms", *Journal of the American Statistical Association*, Vol. 44 (March 1949), pp. 32-61.

<sup>14</sup> R. J. Foote, *Analytical Tools for Studying Demand and Price Structures*. U.S.D.A. Agricultural Handbook 146 (Washington, 1958), p. 169.

<sup>15</sup> Theil and Nagar, *op. cit.*

<sup>16</sup> All equations, except those of the retail model in which the price of lamb was included as a variable, showed significant autocorrelation in the residuals. In no case was there a significant autoregression coefficient beyond the first degree of lag.

these equations showed that the  $e_t$  were not subject to any significant autocorrelation. This attempt to mitigate the effects of autocorrelation may have caused some bias in the estimates because the use of one set of data to generate the initial and corrected estimates, and the autoregression coefficient used for correction, violates the classical set-up of regression theory.<sup>17</sup> Cochrane and Orcutt also warn that the residuals may be biased towards randomness when the explanatory variables and residuals have the same type of autoregressive structure, and the corrective procedure may not go far enough to completely restore the lost efficiency.<sup>18</sup> Thus, it is not possible to decide exactly on the "correct" value of the autoregression coefficient to be used, and this may detract from the optimality of the estimated parameters in the corrected equations.

Because the relationships between the variables were more likely to have been multiplicative than additive, the price and demand equations were all estimated in logarithmic form. Hence, the partial regression coefficients in the demand equations are demand elasticities; and in the price equations they are price flexibilities with respect to supply. The margin equations were estimated in natural form.

The usual test of the significance of regression coefficients, "Students"  $t$ -test, was used in this study. Although its reliability is somewhat doubtful when it is applied to estimates dependent on the calculated autoregression coefficients of the residuals, the 0.05 significance level was used as the test criterion for the estimates.

### *Results*

The following tables summarize the results of the statistical analysis of the models. In each table, the standard errors cited are those relating to the partial regression coefficients. The significance levels refer to the  $t$  test. The " $R^2$ -delete" for each variable is the coefficient of multiple determination which would have been obtained if that variable had been excluded from the equation.

#### *Auction Market*

The results in Table 1 show that changes in the auction price of each meat were quite well explained by the included variables. However, the proportion of the variation in domestic consumption accounted for by the auction prices of the meats was very low. This suggests that the auction demand for meat for domestic consumption was mainly derived from demand in the retail market rather than being autonomously determined by factors in the auction market.

The estimated price equations indicate that the supply of each meat was an important determinant of its own price. In addition, it is evident that the price for mutton was dependent to a large extent on the supply of beef. This suggests that mutton was a substitute for the latter when beef supply was low (and beef prices high). The significance of the export price of beef as a determinant of its auction price was as expected. A similar relation would probably have been observed for mutton and lamb, had it been possible to obtain the export prices for these meats.

<sup>17</sup> Theil and Nagar, *op. cit.*, p. 805.

<sup>18</sup> Cochrane and Orcutt, *op. cit.*, p. 54.



The demand for both beef and lamb was significantly affected only by their own prices, whereas the demand for mutton was influenced equally (but in opposite directions) by the prices of mutton and beef.

TABLE 1  
*Estimated Auction Market Equations<sup>(a)</sup>*

Equation	Dependent variable	Regression constant (b)	Explanatory variable	Partial regression coefficient (b)	Partial correlation coefficient	R <sup>2</sup> delete	R <sup>2</sup>
1	log P <sub>Ba</sub>	0.4785 (0.0831)	log S <sub>B</sub>	-0.3441* (0.0896)	-0.5144	0.4009	0.5595
			log S <sub>S</sub>	-0.0783 (0.0912)	-0.1330	0.5515	
			log P <sub>Bo</sub>	0.5172* (0.1048)	0.6103	0.2979	
2	log P <sub>La</sub>	0.9577 (0.1161)	log S <sub>B</sub>	-0.2844* (0.1302)	-0.3229	0.5690	0.6139
			log S <sub>L</sub>	-0.8460* (0.1429)	-0.6790	0.2838	
			log S <sub>M</sub>	0.2806 (0.2094)	0.2048	0.5970	
3	log P <sub>Ma</sub>	1.2841 (0.1369)	log S <sub>M</sub>	-0.5587* (0.2174)	-0.3725	0.5170	0.5840
			log S <sub>B</sub>	-0.4700* (0.1317)	-0.4870	0.4547	
			log S <sub>L</sub>	-0.3074* (0.1483)	-0.3081	0.5404	
4	log C <sub>B</sub>	0.4868 (0.0453)	log P <sub>Ba</sub>	-0.4951* (0.1652)	-0.4240	0.0808	0.2460
			log P <sub>La</sub>	-0.0333 (0.1303)	-0.0399	0.2448	
			log P <sub>Ma</sub>	-0.0724 (0.1322)	-0.0852	0.2405	
5	log C <sub>L</sub>	0.8098 (0.1657)	log P <sub>La</sub>	-0.7045* (0.2361)	-0.4224	0.2669	0.3977
			log P <sub>Ba</sub>	0.2389 (0.2293)	0.1606	0.3817	
			log P <sub>Ma</sub>	-0.0871 (0.2435)	-0.0558	0.3958	
6	log C <sub>M</sub>	0.2328 (0.0354)	log P <sub>Ma</sub>	-0.2547* (0.0917)	-0.3979	0.1436	0.2792
			log P <sub>Ba</sub>	0.3049* (0.1106)	0.3954	0.1456	
			log P <sub>La</sub>	0.0340 (0.0899)	0.0590	0.2767	

\* Indicates coefficients significant at 0.05 level.

(a) All equations have 42 degrees of freedom.

(b) Numbers in parentheses are standard errors.

This is further evidence that mutton substituted for beef in response to changes in the price of beef. This substitution was probably for the lower grades of beef, which have similar food uses to mutton. The significance of the supply of beef in equation (2) suggests that lamb may also have been a substitute for beef, but this was not confirmed by equation (5).

Despite the high correlation between the supply variables ( $r = 0.91$ ) and prices ( $r = 0.89$ ) for mutton and lamb, collinearity does not appear to have significantly affected these estimates.

TABLE 2  
*Auction-to-Wholesale Margin Equations<sup>(a)</sup>*

Equation	Dependent variable	Regression constant (b)	Explanatory variable	Partial regression coefficient (b)	Partial correlation coefficient	R <sup>2</sup> delete	R <sup>2</sup>
7	$M_{Bw}$	20.4138 (7.5759)	$P_{Ba}$	-0.7654* (0.1474)	-0.6392	0.1071	0.4720
			$C_B$	-0.3274* (0.0830)	-0.5340	0.2614	
			$W_m$	-0.0503 (0.0432)	-0.1833	0.4536	
			$C_L$	0.0098 (0.1323)	0.0119	0.4720	
			$C_M$	0.3006 (0.2986)	0.1592	0.4583	
8	$M_{Lw}$	14.3482 (10.2235)	$P_{La}$	-0.3145* (0.0945)	-0.4704	0.1044	0.3025
			$C_L$	0.0193 (0.2000)	0.0155	0.3024	
			$C_B$	-0.0527 (0.0915)	-0.0918	0.2966	
			$W_m$	-0.0152 (0.0479)	-0.0507	0.3007	
			$C_M$	-0.4857 (0.2989)	-0.2519	0.2553	
9	$M_{Mw}$	12.9421 (3.8242)	$P_{Ma}$	-0.5865* (0.1304)	-0.5843	0.1501	0.4402
			$C_M$	-0.1888 (0.2390)	-0.1255	0.4313	
			$C_B$	-0.0414 (0.0688)	-0.0960	0.4350	
			$W_m$	-0.1087* (0.0418)	-0.3844	0.3432	
			$C_L$	0.0939 (0.1019)	0.1460	0.4281	

\* Indicates coefficients significant at 0.05 level.

(a) All equations have 40 degrees of freedom.

(b) Numbers in parentheses are standard errors.

*Wholesale Market*

The estimates in Table 2 show that for beef both the auction price and the quantity consumed had a significant influence on the auction-to-wholesale margin, the size of which changed inversely with changes in these variables. For mutton and lamb, the influence of their auction prices was similar to beef, but they differed in that quantities consumed were not significant.

The apparent significance of the wage rate in equation (9) is somewhat puzzling. The negative sign of the coefficient implies a decrease in the margin in response to increased labour costs. This is contrary to "normal" entrepreneurial behaviour, and it must be concluded that the perverse sign occurred as the result of multicollinearity between the variables in the estimating equation, or because some unidentified determinant of the margin was excluded from the equation.

The low coefficients of multiple determination in equations (7), (8) and (9) may have been due, in part, to a lack of homogeneity in the pricing policies of individual firms, which caused some "cancelling-out" of the effects of certain factors. However, the major cause was probably the existence of deficiencies in the calculated auction-to-wholesale margins. Although negative values were obtained for some periods, it is unlikely that wholesale firms would in fact have carried losses over the long periods concerned. Negative values could have arisen because the margins were calculated as the difference between two price series which were simple (rather than weighted) averages of prices during each quarterly period.

*Retail Market*

The estimates presented in Table 3 reveal substantially the same relations as were revealed by the auction-to-wholesale margins. The negative sign of the wage-rate coefficient in equation (11) suggests that the significance is spurious, probably for the same reasons as were suggested in relation to equation (9). The highly significant coefficient of beef consumption in equation (12) is additional evidence that mutton was a close substitute for beef.

The equations presented in Table 4 show that the price of each meat was a highly significant determinant of consumption. The consumption of mutton is shown to have been highly dependent on the price of beef and, to a lesser degree, on the price of lamb, as well as on its own price. The significance of the coefficient of lamb price in equation (14b) suggests that there was some substitution of mutton for lamb when the price of the latter rose. The anomalous result obtained in equation (15b) was probably due to multicollinearity, and this equation is regarded as spurious, because it is extremely unlikely, in view of the estimates presented in the preceding tables, that consumption of lamb at retail was not dependent on the price of lamb. Equation (15a) shows that the consumption of lamb was significantly dependent only on its own price. This is regarded as the more realistic result.

Income is not significant in any of the retail demand equations, despite the fact that consumer income was undoubtedly a determinant of the demand for meat. The result obtained here arises from the use of aggregative time series data, which do not reveal the income differentials between groups of consumers. The use of cross-sectional data would

almost certainly result in significant coefficients for income, because it would be possible to distinguish between the demand for meat of consumers in various income-groups.<sup>19</sup>

The estimated partial regression coefficients reveal that the demand for each meat at retail was elastic with respect to its own price. Mutton was the only one of the three meats for which the cross-elasticity of demand with respect to the price of the others was high ( $-1.0913$  for beef price and  $0.7895$  for lamb price). This result further supports the

TABLE 3  
*Wholesale-to-Retail Margin Equations<sup>(a)</sup>*

Equation	Dependent variable	Regression constant (b)	Explanatory variable	Partial regression coefficient (b)	Partial correlation coefficient	R <sup>2</sup> delete	R <sup>2</sup>
10	$M_{Br}$	12.1829 (5.8983)	$P_{Bw}$	-0.9650* (0.1137)	-0.8055	0.1615	0.7055
			$C_B$	-0.2930* (0.0673)	-0.5718	0.5625	
			$W_r$	0.0362 (0.0261)	0.2170	0.6910	
			$C_L$	-0.0264 (0.0998)	-0.0423	0.7050	
			$C_M$	0.2544 (0.1914)	0.2082	0.6922	
11	$M_{Lr}$	56.5158 (11.1876)	$P_{Lw}$	-0.4285* (0.1472)	-0.6283	0.4141	0.6454
			$C_L$	0.0375 (0.2586)	0.0401	0.6448	
			$W_r$	-0.1320* (0.0452)	-0.6293	0.4128	
			$C_B$	-0.0706 (0.1030)	-0.1867	0.6325	
			$C_M$	0.1557 (0.2792)	0.1529	0.6369	
12	$M_{Mr}$	21.6943 (4.7417)	$P_{Mw}$	-0.5905* (0.1028)	-0.6769	0.0986	0.5116
			$C_M$	-0.3104 (0.1656)	-0.2875	0.4676	
			$W_r$	-0.0393 (0.0239)	-0.2541	0.4779	
			$C_B$	-0.1818* (0.0480)	-0.5184	0.3321	
			$C_L$	-0.1591 (0.0814)	-0.2986	0.4638	

\* Indicates coefficients significant at 0.05 level.

<sup>(a)</sup> Equations (10) and (12) have 40 degrees of freedom. Equation (11) has 14 degrees of freedom.

<sup>(b)</sup> Numbers in parentheses are standard errors.

<sup>19</sup> The source and derivation of the income data are discussed in the appendix.

TABLE 4

*Estimated Retail Demand Equations<sup>(a)</sup>*

Equation	Dependent variable	Regression constant (b)	Explanatory variable	Partial regression coefficient (b)	Partial correlation coefficient	R <sup>2</sup> delete	R <sup>2</sup>
13a	log C <sub>Br</sub>	2.4909 (0.4495)	log P <sub>Br</sub>	-1.6937* (0.2212)	-0.7830	0.2669	0.7164
			log Y	0.1226 (0.3034)	0.0663	0.7151	
			log P <sub>Mr</sub>	-0.0139 (0.1935)	-0.0118	0.7163	
13b	log C <sub>Br</sub>	3.6497 (0.5393)	log P <sub>Br</sub>	-1.3305* (0.1852)	-0.9079	0.6703	0.9421
			log P <sub>Lr</sub>	0.0228 (0.1780)	0.0385	0.9420	
			log Y	-0.2397 (0.2020)	-0.3368	0.9347	
14a	log C <sub>Mr</sub>	0.4141 (0.3148)	log P <sub>Mr</sub>	-0.6731* (0.1355)	-0.6324	0.6010	0.7605
			log Y	0.0067 (0.2125)	0.0052	0.7605	
			log P <sub>Br</sub>	0.9825* (0.1550)	0.7215	0.5005	
14b	log C <sub>Mr</sub>	0.3864 (0.4998)	log P <sub>Mr</sub>	-1.0913* (0.1411)	-0.9191	0.7492	0.9610
			log P <sub>Br</sub>	1.2393* (0.1662)	0.9137	0.7642	
			log P <sub>Lr</sub>	0.7895* (0.2966)	0.6259	0.9360	
15a	log C <sub>Lr</sub>	3.1159 (1.2369)	log P <sub>Lr</sub>	-2.0721* (0.4082)	-0.8372	0.5998	0.8803
			log P <sub>Br</sub>	0.4779 (0.4249)	0.3212	0.8665	
			log Y	(0.1445) (0.4634)	0.0936	0.8792	
15b	log C <sub>Lr</sub>	2.0234 (1.0831)	log P <sub>Lr</sub>	-1.0344 (0.6427)	-0.4366	0.8896	0.9106
			log P <sub>Br</sub>	0.9206* (0.3602)	0.6104	0.8576	
			log P <sub>Mr</sub>	-0.6007 (0.3057)	-0.5097	0.8793	

\* Indicates coefficients significant at 0.05 level.

(a) Equations (13a) and (14a) have 38 degrees of freedom. The remainder have 11 degrees of freedom.

(b) Numbers in parentheses are standard errors.

hypothesis that mutton replaced beef in consumer diets when the price of beef rose. The positive sign on the coefficient of lamb price suggests, as previously pointed out, that mutton and lamb were complements in substitution for beef. However, this substitution of lamb for beef was not borne out by the other equations, and it is possible that the significant coefficient of lamb price in equation (14b) was the result of the high correlation ( $r = 0.81$ ) between the retail prices of mutton and lamb.

### *Conclusions*

The quantities of fresh meat entering the N.S.W. domestic market were largely dependent on retail demand. The small proportion of the variation in quantities accounted for by the auction prices was probably due to the impact of price changes on the operations of wholesale firms.

Price determination occurred primarily in the auction market. Wholesale and retail prices can be expressed as the sum of auction price plus the auction-to-wholesale and wholesale-to-retail margins, the size of which varied inversely with movements in the auction price. Changes in the auction price were not fully passed on to wholesale and retail consumers, with the result that wholesale prices were more stable than auction prices, and retail prices were more stable than those at wholesale. This increasing stability of prices may have been due to a variety of reasons, the major one being the costs involved in altering the pricing arrangements of wholesale and retail firms, and the desire of these firms not to alienate their customers by too-frequent price changes. The latter was probably particularly important with respect to the retail market.

The estimated price elasticities of demand for each meat in the auction and retail markets, given in Table 5, show that the elasticity of demand for each meat at retail was considerably higher than at auction. Since the retail demand for each meat has been shown to

TABLE 5  
*Price Elasticities of Demand for Meat*

Meat	Price elasticity at auction	Price elasticity at retail
Beef	-0.4951	-1.3305
Lamb	-0.7045	-2.0721
Mutton	-0.2547	-1.0913

determine the quantity of meat entering the domestic market, it must be concluded, despite the low auction market elasticities, that the domestic demand for individual meats was elastic. The price elasticity for total meat has not been estimated in this study, but the constancy of total meat consumption in Australia suggests that this elasticity would be low.

While there are some possible methodological weaknesses in this study, such as the use of a single-equation method of estimation instead

of a simultaneous equation system, the statistical method chosen was dictated by the nature of the data. Although the estimates presented may not be best linear unbiased estimates, they do provide some insights into the structure and functioning of the N.S.W. meat market.

#### APPENDIX

##### *Sources of Data*<sup>20</sup>

##### *Supply of Meat*

Data on meat production were derived from various issues of the *Primary Production Bulletin, Part I, Rural Industries*, published by the Commonwealth Bureau of Census and Statistics. Due to the unavailability of suitable data, no account was taken of interstate movement of carcass meat.

##### *Meat Consumption*

Meat consumption was a residual figure derived by subtracting exports, quantities canned, and changes in stocks from total production. Data other than production were derived from the unpublished records of the Australian Meat Board. All quantities were converted to a carcass-equivalent basis by the use of bone-to-meat ratios for the various types of carcasses.

##### *Price Data*

Auction and wholesale price series, and retail prices for lamb, were derived from information collected by the Division of Marketing and Agricultural Economics of the N.S.W. Department of Agriculture. The retail price series for beef and mutton came from the *Labour Report*, published by the Bureau of Census and Statistics. Retail prices available were for selected cuts of meat. Weighted average retail carcass prices for each meat were estimated from these data. Export prices used were for total Australian exports, and were derived from the *Monthly Bulletin of Oversea Trade Statistics*, published by the Bureau of Census and Statistics.

##### *Non-farm Personal Disposable Income*

Computation of the income data used was rather involved, and space precludes a full discussion here. Full details are given elsewhere.<sup>21</sup> In brief, the series was derived from various annual and quarterly publications of the Commonwealth Commissioner of Taxation and the Bureau of Census and Statistics. The resultant was an estimate of the quarterly non-farm personal disposable income of N.S.W. residents. The exclusion of farm income removed the distorting effects of the wool boom in the early years.

<sup>20</sup> The complete data tables are presented in I. W. Marceau, *Factors Affecting the Demand and Price Structure in the New South Wales Meat Market*, M.Sc.Agr. thesis (University of Sydney, 1965), pp. 102-112.

<sup>21</sup> Marceau, *op. cit.*, pp. 37-39.