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# Supply and Demand Interactions in the New South Wales Prime Lamb Market

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Prime lamb has not received the same level of economic research as Australia's other major livestock markets and knowledge of the lamb market's operations remains relatively limited. This market has experienced increasing problems including highly variable saleyard prices, strong retail competition and calls for market reform. To date, there has been no quantitative mechanism for assessing the potential impacts of these issues on the state or national lamb markets. This paper reports the development of a quarterly econometric model of the New South Wales prime lamb market. The model considers prime lamb as a separate market entity and places emphasis on the demographic influences on supply response. The estimated model is validated under historical dynamic simulation which generates simultaneous equilibrium solutions for twelve endogenous variables. The model's ability to respond to exogenous shocks is established under impact analysis and some proposed uses for the model are indicated.

## 1. Introduction

The Australian prime lamb market has received little economic research attention in comparison to the other major livestock industries. Although prime lamb has averaged eleven per cent of national red meat output since 1950 (AMLC 1987), quantitative analysis of the lamb market has remained relatively neglected. There has been a tendency to consider lamb as a component of either a broader sheep industry supply response (Gruen *et al.* 1967; Freebairn 1973; Reynolds and Gardiner 1980; Jackson 1980; Dewbre, Shaw, Harris and Corra 1985) or of a meat demand system (Main, Reynolds and White 1976; Fisher 1979; Murray 1984; Martin and Porter 1985). While this research has provided an improved understanding of the discrete determinants of lamb supply and demand, it has revealed little of the interactions between these components and the operational dynamics of the lamb market itself.

The lack of lamb market research might be partly attributable to the complexities of Australian lamb production. Lamb is produced under many production systems and environments, often in association with other farm enterprises to which it tends to be of secondary importance. This status is exemplified in New South Wales where less than one-fifth of prime lamb producers are classified as specialists (Vere and Griffith 1984). The number of non-specialist producers may vary significantly from year to year since movement in and out of production usually only requires a ram breed change. Further, lamb exhibits more production and price seasonality than any other major livestock product (Bain and Hearn 1972). The explicit accommodation of seasonality in sheep industry supply response analysis (and its sequential impacts on prices and consumption) requires the use of quarterly data series which are not readily available for some of the important variables (*e.g.* breeding intentions). These aspects make it difficult to consistently define the lamb industry's structure and to accurately quantify its operations at any level of aggregation. Such difficulties have not been as restricting on the demand side of the lamb market where the use of quarterly data has enabled a better appreciation of the factors determining short-run variations in lamb consumption and prices (Main *et al.* 1976; Fisher 1979; Martin and Porter 1985).

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There is a need for an improved understanding of the causal relationships underlying Australia's prime lamb markets. Lamb continues to experience important long-term problems which include highly variable saleyard prices and farm incomes and strong competition in retail demand from other meats. Producers have expressed dissatisfaction with existing marketing systems and there have been some proposals for lamb market reform in New South Wales and Victoria. Until recently there have been no attempts to jointly model lamb supply and demand and thus no appropriate quantitative mechanism has been available for assessing the impacts of events and policy options in the lamb market. Griffith and Vere (1981) estimated a quarterly quantitative model of the Australian prime lamb market which explained breeding dynamics, slaughterings, production, per capita consumption, aggregate demand, and saleyard and auction prices. This work was subsequently refined and extended (Griffith, Findlay and Vere 1986a) and has since been complemented by a similar econometric analysis of the New South Wales lamb market. The estimation and application of this latter model is the subject of this paper.

## 2. Specification of the Economic Model

### 2.1 Theoretical base

The general model specification considers the New South Wales prime lamb market in four blocks which describe breeding intentions, production, consumption and price formation. Figure 1 is a stylised representation of the model's specification and the linkages between the model's four blocks and component variables. The model contains twelve endogenous variables--mating intentions to the three lamb production ram breed categories, two adjusted composite breeding inventories, slaughterings, production, per capita consumption, domestic demand, saleyard and retail prices and total lamb industry revenue--which are represented by five behavioural and seven definitional equations.

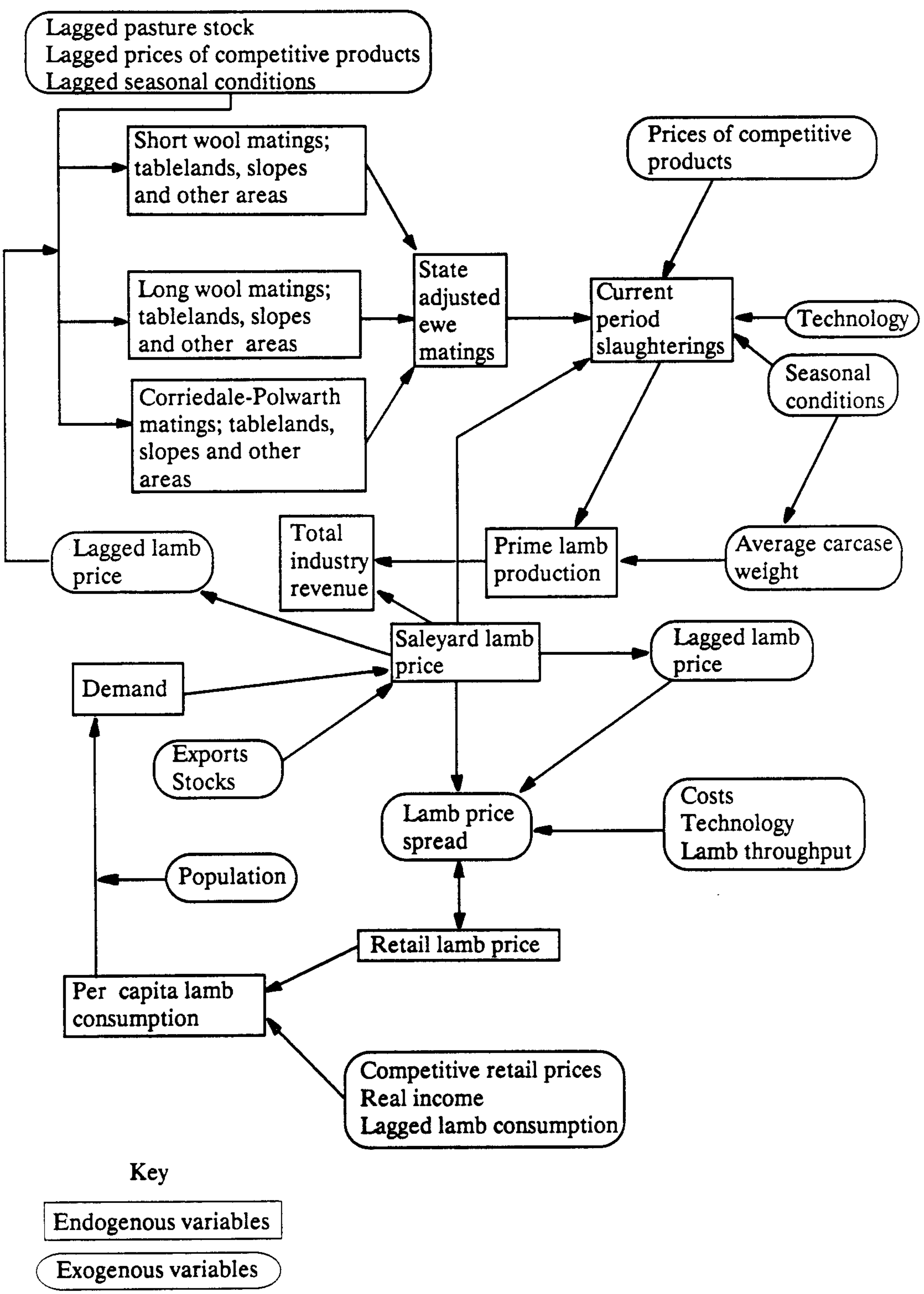
The supply-side specification assumes a recursive relationship between breeding decisions and production, with current period mating intentions to individual ram breeds being determined by lagged values of the explanatory variables. Thus present breeding decisions embody elements of past decisions which in turn are reflected in future output. The overall breeding inventory is regarded as a capital stock which fluctuates according to producers' market price reactions (Jarvis 1974). Price increases encourage investment in breeding stock which leads to a corresponding short-term decline in production as more animals are withheld from slaughter. Production reacts positively in the longer term as the breeding base attains the required level. The magnitude of these changes is dependent on the strength of producers' desires to increase output in response to market price rises. This capital stock assumption is important for this model's lag structure because of the need to adequately represent the temporal links between market price movements and lamb output.

The demand side of the model follows traditional theory where consumption is determined by own and competing product prices, income levels and other exogenous influences. The supply (breeding intentions and production) and demand (consumption and price formation) sides of the lamb market are linked by an equilibrium market clearing condition and by the incorporation of current saleyard and retail lamb prices in the slaughterings and consumption functions respectively.

### 2.2 Breeding block specification

For some livestock categories, a breeding inventory can be defined as an identity comprising changes in opening and closing numbers, slaughterings and natural increase. The lack of slaughterings data for breeding ewes precludes the definition of an inventory identity for the lamb market, but because

**Figure 1: Structural Model of the New South Wales Prime Lamb Market**



decisions to alter lamb output must first involve decisions to alter the breeding base, behavioural equations explaining breeding ewe mating intentions must be estimated.

Breeding decisions for lamb production require consideration of existing ewe numbers, current and expected prices for lamb and other products, and pastoral and seasonal conditions (Reynolds and Gardiner 1980; Griffith and Vere 1981). Freebairn (1973) found that New South Wales lamb production was influenced by opening breeding ewe numbers, the expected returns to lamb production and seasonal conditions. In the absence of disaggregated lamb breed data, Freebairn's lamb production capacity variable was defined as the opening inventory of intended matings to all British breed rams. Four adjustments to these previous structures are required to produce a measure of lamb production capacity which better represents the demographic and temporal features of New South Wales lamb production.

The first adjustment is the disaggregation of the capital stock breeding base into homogeneous components since supply response differs for each category (Reynolds and Gardiner 1980). The breeding base of the New South Wales lamb market comprises different proportions of a variety of British breed ram types which are mated to either cross-bred ewes or to ewes of the same breed. These proportions vary throughout the State according to environmental influences which, in turn, determine demographic breed populations. The State breeding inventory is disaggregated into the three main ram type categories used in prime lamb production: British breed short wool, British breed long wool and Corriedale-Polwarth.

The second adjustment accommodates the varying proportions of total lamb production contributed by the three ram breed categories. Short wool matings (predominantly Poll Dorset) comprise nearly 80 per cent of New South Wales production with all progeny becoming available for slaughter as prime lamb immediately after weaning. Long wool matings (usually Border Leicester rams to aged Merino ewes) generate first-cross progeny with most of the female portion being retained for breeding, and the male portion becoming available for slaughter post-weaning. The same situation holds for the other closed breeds which include Corriedales and Polwarths. An adjustment is made therefore to accommodate the different progeny proportions of the individual ram breeds slaughtered as prime lamb in the next period after weaning. These proportions are specified as 0.95 for short wools, 0.55 for long wools and 0.60 for Corriedales and Polwarths. An assumed five per cent mortality is deducted for each progeny type.

The third adjustment concerns the time lags between breeding decisions and lamb output. An approximate eleven month lag (joining, gestation and weaning) is involved under the traditional second-cross system and for the male and cull ewe lamb portions of long wool and other closed breed matings. The retained ewe portions of these latter joinings result in lamb production some three years hence when they mature and are mated. A breeding inventory-production capacity variable adjusted for ram breed, slaughterings contribution and quarterly production lags is specified as:

$$(1)\quad NSWX = \delta^{SW} ESLW + \delta^{LW} EBLW + \delta^{CP} EBCP + (1 - \delta^{LW}) EBLW_L + (1 - \delta^{CP}) EBCP_L$$

where,

NSWX = New South Wales total adjusted breeding inventory (m), calculated,
EBSW = New South Wales intended matings to British breed short wool rams (m), ABS,
EBLW = New South Wales intended matings to British breed long wool rams (m), ABS,

EBCP = New South Wales intended matings to Corriedale-Polwarth rams (m), ABS,
$\delta^{SW}$, $\delta^{LW}$, $\delta^{CP}$ = slaughterings contributions adjustment factors for short wool, long wool and Corriedale-Polwarth rams (estimates),
L= lag length (here, eight quarters).

A further adjustment to the raw data series for the matings intentions variables (EBSW, EBLW, EBCP) is noteworthy. These data are only collected each 31 March, so it is necessary to derive a quarterly series from these annual measurements. The approach previously adopted by the authors (Griffith and Vere 1981; Vere and Griffith 1986) was to linearly interpolate the data between the measured values. However this procedure imposed certain characteristics on the data which resulted in autocorrelated estimation errors and very stable solution values under simulation. In the present study, the number of ewes intended to be mated within each breed category is seasonally allocated for the coming year on the basis of industry expert opinion within the New South Wales Department of Agriculture (D.C. Harris, Prime Lamb Specialist, pers. comm.).[1] For each intentions category, the majority of matings occur in the first quarter for lambing in Spring, with a significant proportion mated in quarter three for an Autumn lambing the following year. Much smaller proportions are usually intended to be mated in the second and fourth quarters. This final adjustment yields a second composite breeding inventory (NABI) which represents the seasonal allocation of prime lamb breeding intentions across the three ram breed categories;

(2) NABI = (NSWX(-1) + NSWX(-2) + NSWX(-3) + NSWX(-4))/4

where,

NABI = New South Wales composite adjusted breeding inventory incorporating the seasonal allocation of mating intentions (m).

Behavioural equations for the three breeding inventories are considered to be functions of previous breeding inventory levels, past farm prices (for lamb, beef, mutton, wool and wheat) and the area and quality of improved pastures in previous periods. Farm prices are specified as ratios to represent the price relativities which are thought to influence lamb breeding decisions (Dewbre *et al.* 1985) and to diminish the potentially harmful collinearity associated with livestock saleyard price series (Reynolds and Gardiner 1980). A dependent variable lagged four quarters represents a partial adjustment mechanism (Dhrymes 1971) which recognises the likelihood that biological and economic constraints will prevent the full adjustment of breeding decisions to price changes. Hence actual ewe numbers at the end of any period are likely to be different from the number of ewes desired at the same stage of the previous year. Pasture availability and quality will effectively limit the number of breeding ewes that can be carried and these influences are represented by the lagged area of sown pastures and a lagged dummy variable for drought conditions. A linear time trend is included to reflect technology effects in lamb breeding and husbandry. The behavioural equation specifications are:

(3) $EBSW = f(EBSW_L, APIN_L, DMDT_L, PALN_L/PWLA_L, PALN_L/PWHA_L, T)$
(4) $EBLW = g(EBLW_L, APIN_L, DMDT_L, PALN_L/PWL1_L, PALN_L/PWHA_L, T)$
(5) $EBCP = h(EBCP_L, APIN_L, DMDT_L, PALN_L/PWL1_L, PALN_L/PWHA_L, T)$

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[1] The estimated quarterly intended matings to British breed short wool, long wool and Corriedale-Polwarth rams are 0.50, 0.05, 0.30, 0.15 for quarters 1 (Spring) to 4; 0.40, 0.05, 0.30, 0.25; and 0.70, 0.05, 0.20, 0.05, respectively.

where,

EBSW, EBLW, EBCP, are defined as for equation (1),
APIN = New South Wales area of improved pastures (m ha), ABS,
PALN = real[2] saleyard lamb price, dressed carcase weight, Homebush (c/kg), New South Wales Department of Agriculture,
PWLA = real average Australian greasy price for all wools (c/kg), AWC,
PWL1 = real average greasy price for 27 micron wool (c/kg), AWC,
PWHA = real Australian wheat price (Australian Standard White grade, $/t), ABARE,
DMDT = drought dummy variable (1 = below average quarterly rainfall, zero otherwise), ABARE,
T = linear time trend 1961 (1) = 1, *etc.*

## 2.3 Lamb slaughterings and production

The joint-product nature of the prime lamb enterprise implies that farm price relativities are important influences on lamb output. For New South Wales, Freebairn (1973) determined a negative relationship between lamb slaughterings and expected profitability because producers withheld ewe lambs from slaughter following a price rise. This finding is consistent with the capital stock assumption regarding the breeding ewe inventory. Nationally, Reynolds and Gardiner (1980) found that current saleyard lamb price was a significant and positive influence on lamb slaughterings, although later work determined a strong negative influence (Reynolds, Weissel and Corra 1981; Reynolds, Carland and Corra 1983). Breeding ewe numbers, pasture availability and quality and seasonal conditions are other important influences on lamb slaughterings.

In an earlier version of this model, New South Wales lamb slaughterings were specified to be a function of the adjusted breeding ewe inventory lagged one period, farm prices, pasture availability and quality, seasonal conditions and technology. Following Griffith *et al.* (1986b), it was found that this model solved with smaller errors compared to the actual data when the slaughterings equation was re-estimated with saleyard price as the dependent variable (see Section 2.4). Slaughterings are now derived from an identity comprising production and average slaughter weight, and the supply side of the model is completed by a market balance identity determining the production of lamb from changes in stocks, aggregate demand and exports:

(6) $SLBN = PLBN/ASWT$
(7) $PLBN = LCST - LCST_L + DMLN + EXLN$

where,

SLBN = New South Wales lamb slaughterings (m), AMLC,
PLBN = New South Wales lamb production (kt), AMLC,
ASWT = average dressed carcase weight (kg/head), calculated, from (6),
LCST = New South Wales closing lamb stocks (kt), AMLC,
DMLN = New South Wales lamb consumption (kt), calculated, as Australian per capita consumption (AMLC) * New South Wales population (m), ABS,
EXLN = New South Wales net lamb exports (kt), calculated, as exports to overseas destinations (AMLC) plus apparent net interstate trade from (7) (Griffith, Freshwater and Smith 1983). Thus interstate trade in lamb is incorporated exogenously in EXLN.

2 All price and value series used in the model were deflated by the CPI, Sydney.

## 2.4 Demand and price block specification

### 2.4.1 Lamb consumption

Lamb is not a preferred product in Australia's retail meat market. Previous quantitative studies of Australian red meat consumption have identified strong competition to lamb from beef and pork and, more recently, from chicken (BAE 1967; Marceau 1967; Gruen *et al.* 1967; Main *et al.* 1976; Fisher 1979). Most cross-price and income elasticities of demand for meat indicate a consumer preference for beef. Moreover lamb demand is own-price elastic and is generally unresponsive to movements in consumer incomes; in fact, it may be negatively income inelastic (Main *et al.* 1976).

From previous evidence, per capita lamb consumption in New South Wales is considered to be determined by the real retail prices of lamb and other meats (beef, pork and chicken), and real per capita disposable income. A chicken price variable is included to test the strength of competition to lamb from chicken in the Australian meat market. Prior estimation revealed a strong correlation between the beef and chicken price series (the partial correlation coefficient was 0.83). This finding confirms Throsby's (1974) observation and the weak impact of retail chicken prices on Australian lamb consumption found by Fisher (1979). Beef and chicken retail prices are included as an index of the two series weighted according to relative consumption levels. Quarterly dummy variables reflect seasonal movements in lamb consumption while a further dummy variable represents the 1974 North American beef price slump which considerably weakened Australia's beef export trade at that time and diverted export beef surpluses onto the domestic market (Griffith, Freshwater, Verspay and Goddard 1985). The inclusion of a lagged dependent variable indicates the degree of habit formation in current lamb consumption. Apparent Australian lamb consumption is derived following AMLC (1988) and Griffith, Freshwater and Smith (1983) (*i.e.* production and opening stocks less exports and closing stocks); per capita consumption is aggregate consumption divided by the Australian population; while total New South Wales lamb consumption is the product of Australian per capita lamb consumption and the State population :

(8) $DCLA = f(DCLA_L, RINA, PRLN, PRBC, PRPN$, plus quarterly and impact dummies),
(9) $DMLN = DCLA * POPN$

where,

DCLA = Australian per capita lamb consumption (kg/head), AMLC,
RINA = real household disposable income ($'000), ABS,
PRLN = real retail lamb price, Sydney (c/kg), New South Wales Department of Agriculture,
PRBC = weighted index of real retail beef and chicken prices, Sydney (c/kg),
PRPN = real retail pork price, Sydney (c/kg), New South Wales Department of Agriculture,
DMLN, POPN are as previously defined.

### 2.4.2 Lamb prices

Other research has investigated the process of price determination in the lamb market (Griffith *et al.* 1986b). That work considered the impact of four alternative price determination processes on the validation performance of the national lamb market model described in Griffith *et al.* (1986a). A price dependent slaughterings specification was found to best capture the causality of lamb slaughterings on saleyard price. Accordingly, saleyard lamb price is determined by estimating an inverted lamb slaughterings equation in which the lagged adjusted breeding inventory averaged over the four quarters, current slaughterings, pasture quality and lagged wool prices and quarterly dummies are the specified explanatory variables. The inclusion of an impact dummy variable for the 1974 North American beef export shock complements the reasoning in the previous section and is expected to have a negative influence on lamb's saleyard price.

The retail price of lamb is defined as the saleyard price plus the margin. Here the marketing margin between saleyard and retail prices is specified exogenously since it improves the model's validation performance.[3] Lamb carcase weight and lamb exports are also assumed to be exogenous. The lamb price block contains an equation for saleyard price and identities for retail price and total industry revenue:

(10) PALN = f(NABI, SLBN, PFZN, $PWL1_L$, plus quarterly and impact dummies),
(11) PRLN = PALN + MMLN
(12) TREV = PLBN * PALN

where,

PFZN = area of improved pastures fertilised, New South Wales (m ha), ABS,
TREV = real total lamb industry revenue ($'000), calculated, from (12), and the other variables are defined as before.

## 3. Model Estimation and Validation

### 3.1 Methods

The model was estimated over 64 quarterly observations between 1969(1) to 1984(4) using the TSP (version 4.1) econometric package. Breeding decisions are closely related because intentions for one ram type will influence those for another, *e.g.* second-cross mating decisions will influence the intentions of first-cross breeders because first-cross ewes are the basis of second-cross lamb production. Such close relationships indicate the likelihood of residual correlation across the set of specified breeding inventory equations with a corresponding loss of estimation efficiency (Zellner 1962). This problem was overcome by estimating these equations as a set of seemingly unrelated regressions given that the explanatory variable sets are not identical in each equation. The remaining equations were estimated by ordinary least squares, except for the long wool equation which was estimated by maximum likelihood with an assumed first-order autocorrelated error structure using TSP's AR1 procedure. The complete model was validated under dynamic, deterministic simulation over the structural estimation period. By utilizing predicted rather than actual values for the lagged

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[3] The estimated equation for the lamb marketing margin was;

$$\underset{(-3.30)}{\text{MMLN} = -92.0} + \underset{(2.27)}{0.84\,\text{WAGE}} + \underset{(3.48)}{1.07\,\text{PLBN}} + \underset{(9.28)}{0.85\,\text{PRLN}} - \underset{(-0.71)}{1.27\,\text{DUMQ1}} - \underset{(-1.95)}{3.83\,\text{DUMQ2}} - \underset{(-3.21)}{5.82\,\text{DUMQ3}}$$

$R^2 = 0.72$; DW = 1.81; rho = 0.59; N = 64.

where,

MMLN = real saleyard-retail price spread for lamb (c/kg), calculated from (11),
WAGE = wages paid in the meat processing sector ($/week), ABS, and the other right hand side variables are defined as before.

The summary statistics for the dynamic simulation (as in Table 3) were all adversely affected when this equation was included in the model, *e.g.* the squared correlation coefficients were reduced while the coefficients of actuals on predicteds were further away from unity.

endogenous variables, this procedure provides a more rigorous evaluation of the model's predictive capacity. The model was further subjected to a beyond-sample validation over 1985(1) to 1987(2) as a test of its ability to simulate actual data series outside the estimation period.

## 3.2 Estimation and validation results

### 3.2.1 Structural equation estimates

The structural equation estimates are presented in Table 1. The breeding inventory estimates indicate that current period mating intentions are strongly influenced by mating decisions in the previous year and farm price movements. While this result is partly due to the constructed nature of the inventory variables, the equations can be considered as explanations of the annual changes in intentions rather than of their levels at any point in time. The structured nature of the breeding intentions data means that the longer term elasticities (derived from the partial adjustment coefficients) are measured annually and hence are much larger than the short-term estimates. It is apparent that changes in farm price relativities are important influences on lamb breeding decisions, particularly those involving short wool and Corriedale-Polwarth rams (although it is recognised that price elasticities derived from price ratios are not strictly comparable to an elasticity from a linear price coefficient). Improved pasture levels influence lamb breeding decisions in the longer term while second-cross and first-cross lamb production intentions are affected by drought conditions eight quarters prior as producers increase lamb production.

New South Wales lamb consumption is influenced by real incomes and real retail prices and displays a strong incidence of habit formation. The state-level cross-price elasticities between lamb and the composite beef-chicken prices are similar to those reported elsewhere for Australia (Main *et al.* 1976; Fisher 1979) (Table 2). The results confirm the importance of lamb's retail price as a consumption determinant but, overall, lamb consumption is relatively unresponsive to retail meat price movements. Lamb consumption is negatively related to real income and exhibits an approximate 40 per cent decline to increases in current real income. The longer-term effect is much greater. The sensitivity of state lamb consumption to periodic events in Australia's principal meat export markets is evidenced by the significant impact dummy variable. This external event stimulated domestic lamb consumption when export beef surpluses diverted onto the local market caused falls in the saleyard prices of beef (Griffith *et al.* 1985) and lamb alike.

Saleyard lamb prices are influenced by current pasture quality and previous wool prices but are most responsive in the short term to lamb slaughtering levels. The price flexibility estimate on the lamb slaughterings variable indicates an approximate proportional negative price response to lamb throughput changes (the corresponding supply elasticity estimate was -1.3). The lamb price shock from the 1974 final quarter US beef price slump is consistent with its effect on lamb consumption, but it had dissipated two quarters hence.

Each of the structural equations was tested for higher-order autocorrelation using a Lagrange multiplier test for lag lengths of one, four and eight periods, both separately and together. The computed chi-squared value for each lag length was insignificant at five per cent for the equations representing short wool mating intentions, lamb consumption and lamb saleyard price. There was evidence of eighth-order autocorrelation in the Corriedale-Polwarth equation and in the long wool equation for all lag lengths. The long wool equation was estimated assuming first-order autocorrelated errors (the problem of some remaining higher-order autocorrelation is recognised). Also, this model's breeding block lag specifications are considered to accurately represent the operational dynamics of the prime lamb production systems in New South Wales.

**Table 1: Structural Equation Estimates for the New South Wales Lamb Model**

| Dependent Variable | Estimation Method[a] | Equation Estimates 1969(1) to 1984(4) | Adj. $R^2$ | DW | h | SEE[b] | rho |
|---|---|---|---|---|---|---|---|
| Short wool matings | SUR | EBSW = - 0.416 + 0.983 EBSW(-4) + 0.058 APIN(-8)<br>(-1.95) (62.07) (1.89)<br>{0.06/3.24}<br>+ 0.086 DMDT(-8) - 0.579 PALN(-8)/PWLA(-8)<br>(1.89) (-2.34)<br>{-0.05/-2.75}<br>+ 0.506 PALN(-8)/PWHA(-8)<br>(3.98)<br>{0.07/3.88} | 0.98[c] | | -1.54 | 0.03 | |
| Long wool matings | SUR | EBLW = - 0.263 + 0.832 EBLW(-4) + 0.080 APIN(-8)<br>(-1.27) (19.69) (2.72)<br>{0.11/0.63}<br>+ 0.095 DMDT(-8) - 0.682 PALN(-8)/PWL1(-8)<br>(2.43) (-2.87)<br>{-0.05/-0.29}<br>+ 0.171 PALN(-8)/PWHA(-8)<br>(2.18)<br>{0.03/0.19} | 0.97[c] | | -0.78 | 0.03 | 0.04<br>(1.90) |
| Corriedale-Polwarth matings | SUR | EBCP = - 0.064 + 0.942 EBCP(-4) + 0.023 APIN(-8)<br>(-0.67) (43.57) (1.73)<br>{0.10/1.67}<br>- 0.599 PALN(-8)/PWL1(-8) + 0.138 PALN(-8)/PWHA(-8)<br>(-4.10) (2.68)<br>{-0.14/-2.40} {0.08/1.34} | 0.96[c] | | -0.45 | 0.05 | |
| Lamb consumption | OLS | DCLA = 4.540 + 0.384 DCLA(-1) - 0.004 RINA<br>(3.16) (3.59) (-2.35)<br>{-0.41/-0.67}<br>+ 0.011 PRBC + 0.007 PRPN - 0.021 PRLN<br>(3.18) (1.20) (-4.65)<br>{0.39/0.63} {0.21/0.33} {-0.50/-0.82}<br>- 0.705 DUMQ1 - 0.611 DUMQ2 - 0.020 DUMQ3<br>(-3.63) (-2.62) (-0.11)<br>+ 0.751 DUM74<br>(1.99) | 0.86 | | -0.91 | 0.08 | |
| Lamb saleyard price[d] | OLS | PALN = 30.232 + 3.029 NABI + 6.919 PFZN<br>(7.73) (1.03) (9.34)<br>{0.24} {0.56}<br>- 18.917 SLBN + 0.029 PWL1(-1) + 1.640 DUMQ1<br>(-4.78) (2.11) (1.22)<br>{-0.83} {0.27}<br>+ 3.241 DUMQ2 + 4.503 DUMQ3 - 12.064 DUM74<br>(2.51) (3.50) (-3.12)<br>- 7.480 DUM74(-1)<br>(-1.97) | 0.82 | 1.85 | n.a. | 0.10 | |

[a]Zellner's Seemingly Unrelated Regressions; [b]proportion of dependent variable mean; [c]adjusted $R^2$ of underlying OLS equation for comparison; [d]numbers in { } are flexibilities; n.a. = not available; numbers in {/} are short and long run elasticities at the sample means; N = 64.

**Table 2: Retail Demand Elasticities for Lamb (t values in brackets)**

| Study | Estimation Method | Retail Prices: Beef | Lamb | Pork | Mutton | Chicken | Real Income | Level | Data Period |
|---|---|---|---|---|---|---|---|---|---|
| Van der Meulen (1961) | OLS | 0.913 | -1.184 | - | - | - | 0.225 | NSW | annual |
| | (linear) | (22.816) | (-94.725) | | | | (2.984) | | |
| Marceau (1967) | OLS (C O) | 0.478 | -2.072 | - | - | - | 0.145 | NSW | quarterly |
| | (double log) | (1.125) | (-5.076) | | | | (0.311) | | |
| Marceau (1967) | OLS (C O) | 0.921 | -1.034 | - | -0.601 | - | - | NSW | quarterly |
| | (double log) | (2.556) | (-1.610) | | (1.965) | | | | |
| Gruen et al. (1968) | OLS | 0.626 | -1.395 | - | 0.031 | - | 0.451 | AUST | annual |
| | (double log) | (6.879) | (-8.774) | | (0.230) | | (2.548) | | |
| Main, Reynolds and White (1976) | OLS (C O) | 0.710 | -1.684 | 0.857 | 0.247 | - | 0.028 | AUST | quarterly |
| | (double log) | (3.331) | (-4.982) | (3.001) | (0.751) | | (0.245) | | |
| Main, Reynolds and White (1976) | SUR | 0.642 | -1.894 | 0.911 | 0.482 | - | -0.138 | AUST | quarterly |
| | (double log) | (4.495) | (-6.479) | (4.842) | (1.764) | | (-1.467) | | |
| Fisher (1979) | FIML | 0.720 | -1.660 | 0.370 | 0.230 | - | 0.030 | AUST | quarterly |
| | (double log) | (8.790) | (-10.850) | (3.830) | (1.580) | | (0.760) | | |
| Fisher (1979) | FIML | 0.470 | -1.580 | 0.330 | 0.250 | -0.120 | 0.090 | AUST | quarterly |
| | (double log) | (5.730) | (-11.170) | (3.780) | (2.000) | (-2.520) | (2.520) | | |
| Griffith and Vere (1981) | OLS | 0.950 | -1.330 | 0.600 | - | | 0.090 | AUST | quarterly |
| | (linear) | (13.200) | (-16.140) | (4.020) | - | | (1.160) | | |
| Griffith and Vere (1981) | 2SLS | 1.100 | -1.610 | 0.870 | - | | 0.250 | AUST | quarterly |
| | (linear) | (5.100) | (-4.080) | (2.150) | | | (1.090) | | |
| BAE (1983) | OLS | 0.560 | -1.440 | 0.070 | 0.110 | 0.240 | 0.15 | AUST | annual |
| | (linear) | | | | | | | | |
| Vere and Griffith (1984) | OLS | 0.23/0.54 | -0.34/-0.80 | 0.29/0.68 | | | -0.27/-0.64 | NSW | quarterly |
| | (linear) | (1.60) | (-2.29) | (1.19) | | | (-1.39) | | |

### 3.2.2 Dynamic simulation results

Table 3 contains the summary statistics for the validation dynamic simulation (including projection error decomposition) for the twelve endogenous variables, while Figure 2 illustrates the comparison between the actual and predicted series for lamb production, lamb demand and saleyard and retail lamb prices. The simulation results confirm the model's ability to accurately replicate the actual data over long periods and so reflect the operational dynamics of the New South Wales lamb market. In the main, the simulated series closely track the actual data and capture most of the turning points. The squared correlation coefficients for all of the endogenous variables indicate that the model explains a high proportion of variation in the actual data when the current period interactions between the model's simultaneously determined endogenous variables and the dynamic interactions of all the lagged endogenous variables are considered. The root-mean-squared errors (expressed as ratios of the endogenous variable means) are all small, and negligible bias is evident in the predicted series which display similar stability to the actual data. Residual variance is the main source of prediction error for all the endogenous variables.

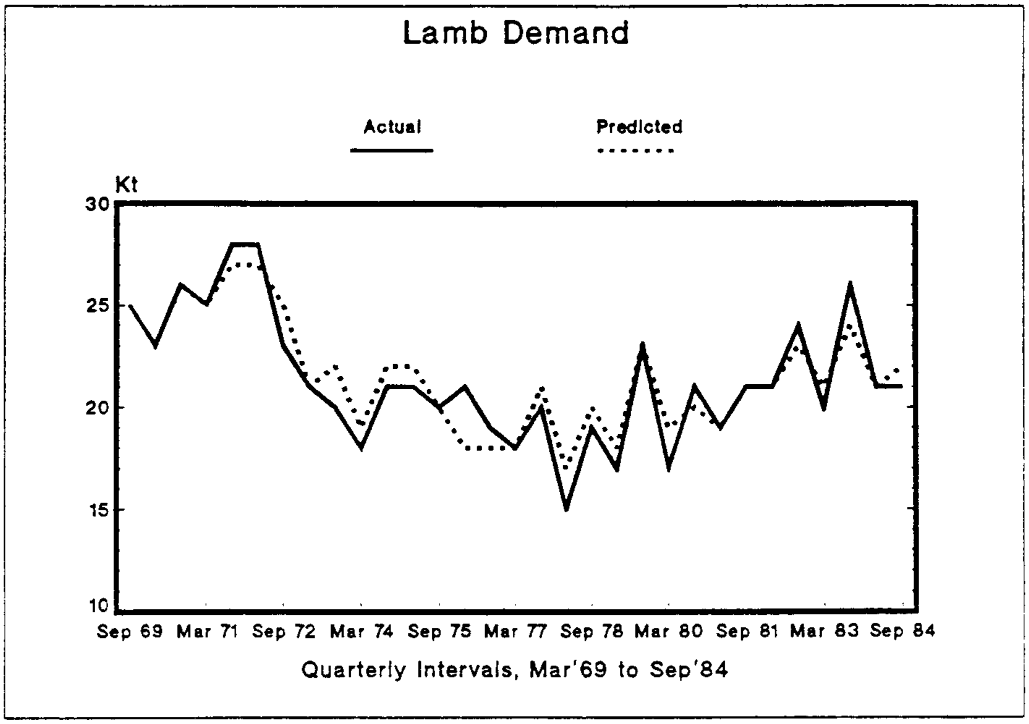
**Table 3: Ex post Dynamic Validation of the New South Wales Lamb Model: 1969(1) to 1984(4)**

| Endogenous variable | Correlation coefficient squared | Root mean square error (% of mean) | Theil statistic (U) | % Error due to bias | % Error due to B≠1 | Coefficent of actual on predicted |
|---|---|---|---|---|---|---|
| EBSW | 0.98 | 0.03 | 0.103 | 0.00 | 0.28 | 1.11 |
| EBLW | 0.79 | 0.07 | 0.256 | 0.05 | 0.15 | 1.32 |
| EBCP | 0.96 | 0.05 | 0.144 | 0.05 | 0.00 | 0.99 |
| NSWX | 0.97 | 0.04 | 0.122 | 0.02 | 0.41 | 1.17 |
| NABI | 0.91 | 0.04 | 0.043 | 0.19 | 0.00 | 1.00 |
| SLBN | 0.86 | 0.06 | 0.061 | 0.01 | 0.00 | 1.01 |
| PLBN | 0.86 | 0.06 | 0.061 | 0.01 | 0.00 | 1.00 |
| DCLA | 0.86 | 0.07 | 0.072 | 0.01 | 0.01 | 1.03 |
| DMLN | 0.78 | 0.07 | 0.073 | 0.01 | 0.02 | 1.01 |
| PALN | 0.80 | 0.11 | 0.105 | 0.01 | 0.01 | 1.06 |
| PRLN | 0.95 | 0.03 | 0.035 | 0.00 | 0.00 | 1.01 |
| TREV | 0.81 | 0.09 | 0.091 | 0.00 | 0.01 | 0.95 |

### 3.2.3 Beyond-sample dynamic validation

The results of the beyond sample dynamic validation between 1985(1) and 1987(2) are presented in Table 4. The solution values for most of the endogenous variables are comparable to those for the full sample validation although substantial bias is evident. The similarity between the two sets of validation results suggests that no additional errors are introduced over this very short ten-period simulation.

**Figure 2: Comparison of Actual and Predicted Series for Selected Endogenous Variables**



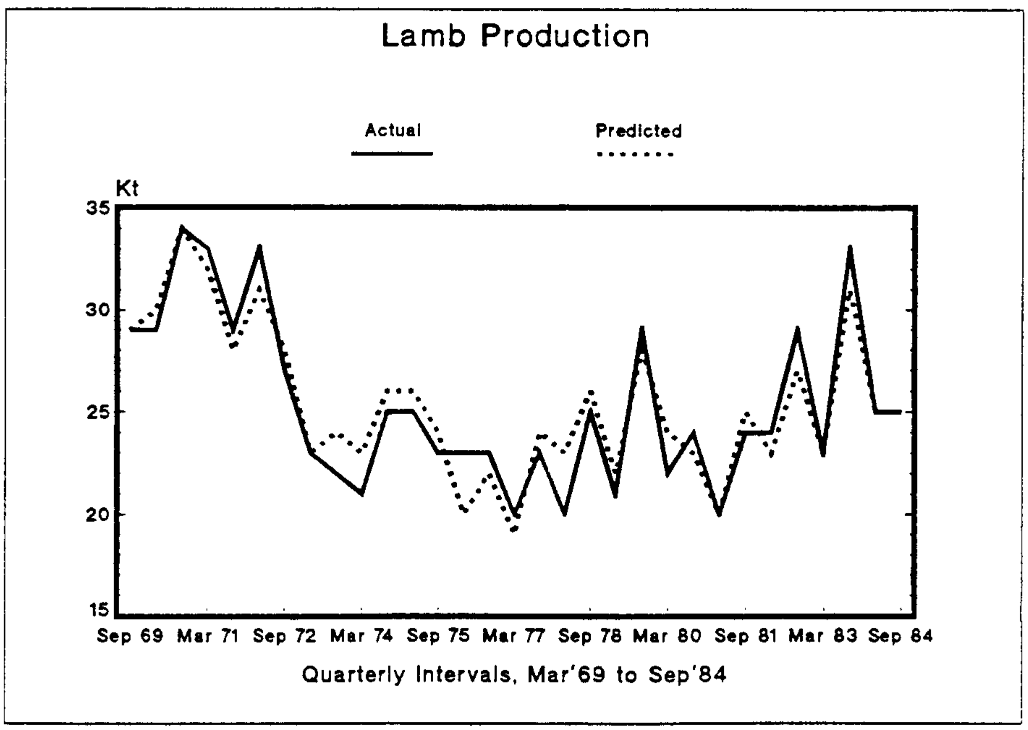
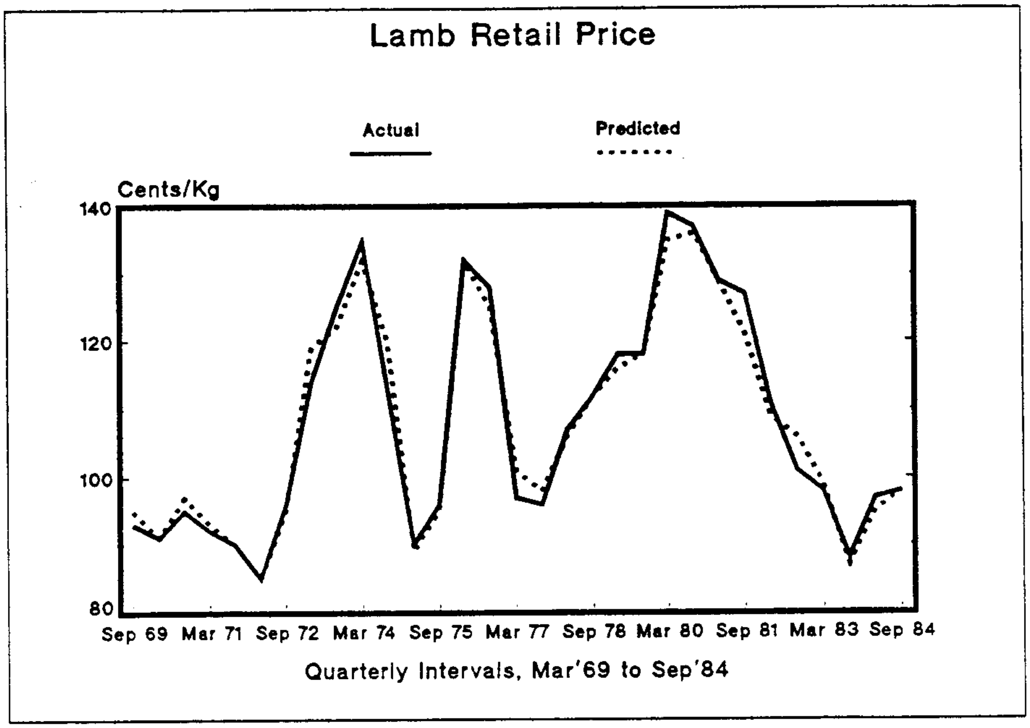



**Figure 2 (continued..)**



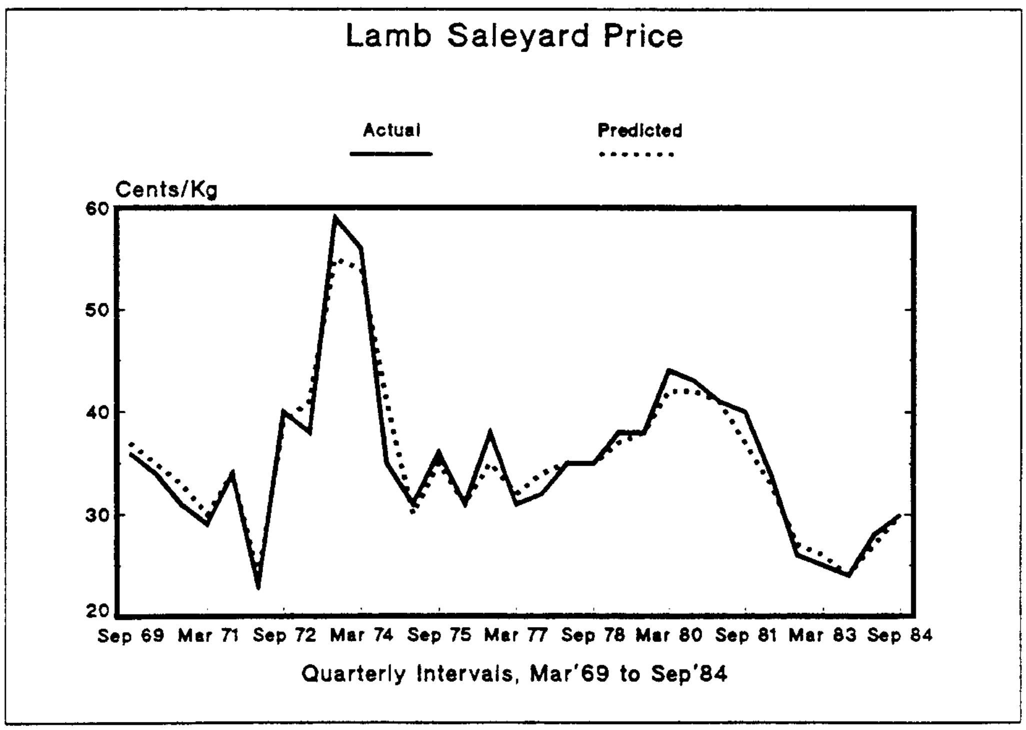



**Table 4: Beyond-sample Dynamic Validation of the New South Wales Lamb Model: 1985(1) to 1987(2).**

| Endogenous variable | Correlation coefficient squared | Root mean square error (% of mean) | Theil statistic (U) | % Error due to bias | % Error due to B≠1 | Coefficient of actual on pre dicted |
|---|---|---|---|---|---|---|
| EBSW | 0.99 | 0.02 | 0.080 | 0.28 | 0.47 | 0.91 |
| EBLW | 0.98 | 0.02 | 0.093 | 0.27 | 0.16 | 1.08 |
| EBCP | 0.99 | 0.04 | 0.158 | 0.64 | 0.15 | 1.09 |
| NSWX | 0.99 | 0.04 | 0.040 | 0.34 | 0.28 | 0.96 |
| NABI | 0.97 | 0.02 | 0.017 | 0.82 | 0.01 | 1.04 |
| SLBN | 0.90 | 0.09 | 0.091 | 0.78 | 0.06 | 0.83 |
| PLBN | 0.92 | 0.09 | 0.091 | 0.78 | 0.05 | 0.87 |
| DCLA | 0.82 | 0.09 | 0.102 | 0.78 | 0.11 | 0.71 |
| DMLN | 0.81 | 0.10 | 0.102 | 0.78 | 0.09 | 0.68 |
| PALN | 0.85 | 0.33 | 0.576 | 0.92 | 0.07 | 0.45 |
| PRLN | 0.98 | 0.11 | 0.130 | 0.92 | 0.05 | 0.80 |
| TREV | 0.26 | 0.24 | 0.432 | 0.94 | 0.04 | 0.26 |

## 3.3 Impact analysis

While periodic shocks in the Australian livestock markets can be expected to be reflected in the data time-series for the market variables, differences in the patterns of occurrence and intensity suggest that their impacts on a particular market would vary considerably. The New South Wales lamb market has experienced recurring shocks (*e.g.* drought and farm price cycles), sporadic shocks (*e.g.* the 1974 US beef price slump and the loss of the Iranian lamb export market in 1980) and permanent shocks resulting from government policy (*e.g.* the introduction of the wool reserve price scheme in 1974 and the large fertilizer price rises in 1976). The impact of two such shocks are examined in this section.

The impact analysis procedure adopted was to alter the level of the relevant exogenous variable for one or more periods, re-simulate the model and compare the new solution values with those of the prior validation simulation. The objective is to establish the model's ability to respond to exogenous shocks and regain equilibrium, and so determine its usefulness for assessing the industry impacts of actual and hypothesised events. Shock effects are assessed in terms of the percentage deviations of the endogenous variable values from their validation solution values. The two shocks examined are a 30 per cent increase in wool price in the first quarter of 1972 and the non-occurrence of the US beef price slump at the end of 1974. The former is a major explanatory variable in the structural component of the model (occurring in three of the five behavioural equations), while the latter is an example of a sporadic shock which was truly external to the New South Wales lamb market.

Despite the severe wool price depression which occurred in 1969-70, a large simulated increase in wool price in the following year induces only minor changes in lamb supply and demand (Table 5). The impact on all endogenous variables declines rapidly over successive quarters and the model regains equilibrium before the end of the simulation sample period. However removal of the 1974 impact dummy has an immediate and significant effect on lamb production, consumption and prices.

**Table 5: Impact Analysis for Two Simulated Shocks**

| Endogenous variable | Unit | Change in Endogenous Variable from Shock: Wool Price Increase [a] first quarter of change | per cent change | equilibrium regained [c] | No US Beef Price Slump [b] first quarter of change | per cent change | equilibrium regained [c] |
|---|---|---|---|---|---|---|---|
| EBSW | million | 72 (2) | 0.55 | 77 (1) | 74 (4) | -4.54 | 76 (1) |
| EBLW | million | 72 (2) | -1.41 | 84 (1) | 74 (4) | -4.31 | 84 (1) |
| EBCP | million | 72 (2) | -0.70 | 84 (1) | 74 (4) | -17.16 | 84 (1) |
| NSWX | million | 72 (2) | 0.70 | 81 (1) | 74 (4) | -4.36 | 74 (2) |
| NABI | million | 72 (2) | -0.17 | 81 (1) | 74 (4) | -0.90 | 80 (1) |
| SLBN | million | 72 (2) | -0.35 | 72 (3) | 74 (4) | -12.54 | 76 (1) |
| PLBN | kt | 72 (2) | -0.31 | 73 (1) | 74 (4) | -12.55 | 76 (1) |
| DCLA | kg/head | 72 (2) | -0.42 | 72 (3) | 74 (4) | -13.72 | 76 (1) |
| DMLN | kt | 72 (2) | -0.40 | 73 (1) | 74 (4) | -13.66 | 76 (1) |
| PALN | c/kg | 72 (2) | 1.83 | 73 (1) | 74 (4) | 46.71 | 76 (1) |
| PRLN | c/kg | 72 (2) | 0.63 | 72 (3) | 74 (4) | 13.14 | 76 (1) |
| TREV | $'000 | 72 (2) | 1.56 | 72 (3) | 74 (4) | 28.44 | 76 (1) |

Notes : a 30 per cent increase in 1972 (1); b 1974 (4) = 1 for dummy variable, = 0 for impact simulation; c change < 0.02 per cent.

It appears that New South Wales lamb would have faced substantially reduced market competition from beef had beef prices not crashed in Australia's principal export market. Inspection of the full impact simulation results indicates that these immediate effects are rapidly diluted as prices are eroded by production increases. The overall result is that events of significance in the New South Wales lamb market are generally short-lived because of the balancing relationships between market supply and demand. The model's ability to regain an equilibrium position indicates that even a major shock or an exogenous shift of lasting impact would still result in a position of long-term market equilibrium.

## 4. Conclusions

This paper describes the development and estimation of a structural econometric model of the New South Wales prime lamb market. The model comprises a system of twelve behavioural and definitional equations which represent the main economic variables in the lamb market. The supply and demand relationships for lamb are considered in terms of the dynamic interactions between their breeding, production, consumption and price components. The model determines three individual and two adjusted inventories of lamb breeding intentions which flow recursively into three simultaneously determined lamb production (slaughterings and total production), lamb demand (per capita and aggregate consumption) and lamb price (saleyard and retail) blocks. An additional identity determines total industry revenue. The supply and demand sides of the market are linked by an equilibrium condition with current prices influencing both the production and demand blocks.

This model differs from previous research on several grounds. Foremost, the model considers the New South Wales prime lamb market as a separate entity rather than as a component of the broader sheep and wool industry. This approach has enabled a more rigorous representation of the relationships and operational dynamics in this State's lamb market. Second, the model utilizes quarterly data which should more precisely explain the consequences of short-run movements in the determinants of lamb output, prices and consumption levels. Quarterly data can also be expected to better capture the high production and price seasonality which characterises the Australian prime lamb industry. Further, the model places emphasis on those demographic factors which underlie the New South Wales lamb market's structure and influence production decisions. The explicit incorporation of the demographics of supply response through the population breakdowns, breed slaughtering contributions, production lags and the patterns of quarterly matings associated with the three main ram breed categories is expected to provide an improved measure of lamb production capacity and the sequential impacts of breeding decisions throughout the lamb market.

The approach to modelling the New South Wales prime lamb market described in this paper has enabled the development of an economic framework which should provide an improved basis for assessing the impacts of lamb market developments, policies and shocks to the industry. To date, earlier versions of this model have been used to evaluate price band stabilization proposals in the New South Wales lamb market (McInnes *et al.* 1986) and the impact of potential productivity innovations in various livestock research areas. The model should also enable improved projections to be made of the main economic variables in the lamb market. The typical joint-product nature of the lamb enterprise and the substitutability of meats at retail make projections of future lamb prices and quantities important inputs in lamb market decisions. Lamb production forecasts are regularly required for example, by the New South Wales Meat Production Forecasting Committee.

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