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ALTERNATIVE BREEDING INVENTORY SPECIFICATIONS IN A LIVESTOCK MARKET MODEL

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The procedures adopted for incorporating breeding decisions in a livestock market model have implications for the simulation of the model. Specifically, there is a need to consider the nature of the biological lags between livestock breeding decisions and outputs, and how these are incorporated in the breeding inventory used in such a model. In this paper, five alternative breeding inventory specifications are used in a structural econometric model of the Australian prime lamb market. The predictions of lamb slaughterings and of price responses of lamb producers are affected by the specification of the lamb breeding inventory used. The extent to which the modelling results approximated reality was substantially improved when disaggregated and seasonally allocated data were used to estimate lamb breeding inventories.

Introduction

To model the operations of livestock markets realistically, it is necessary to represent breeding inventories accurately. Extensive livestock production systems exhibit long lags between breeding decisions and outputs because of seasonal and pasture growth cycles. Livestock production decisions are recursive. Current breeding intentions reflect previous breeding decisions and, together, these influence future output. The breeding inventory is the capital good of a livestock industry (Jarvis 1974). Thus, it is a major determinant of supply response, and of the subsequent price and consumption processes. The precision with which the breeding inventory is modelled will strongly influence the estimated values of the other market variables, particularly in livestock production processes which take a long time (Nerlove 1979).

A common problem in modelling livestock breeding inventories is quantifying the lags in production responses to price changes and in doing so, incorporating realistic assumptions about price expectations (Anderson 1974). There is a large amount of literature which shows that both past and anticipated prices are important determinants of production plans. However, regular production cycles in the extensive livestock industries in some countries have also been found, especially for cattle. These cycles arise because production decisions are based more on biological constraints than on producers' responses to changes in prices and other economic variables (Rucker, Burt and LaFrance 1984). Further-more, research on this issue has found a low response to prices in decisions about livestock breeding (e.g., Freebairn 1973; Fisher and Munro 1983 in Australia; and Kulshreshtha and Wilson 1972; Tryfos 1974; Arzac and Wilkinson 1979 in North America). Such findings appear to be inconsistent with the various price expectations hypotheses utilised in supply response analysis. More plausibly, they indicate the importance of breeding constraints in livestock supply response, and emphasise the need for the explicit incorporation of these constraints into the model if it is to be a realistic representation of the operations of the market.

In this paper, the effects of alternative specifications of breeding inventory on the estimates obtained from a quarterly econometric model of the Australian prime lamb market are investigated. One aim was to develop a measure of the capacity to produce lamb which explicitly incorporated the lags between breeding decisions and output, and their subsequent effects on the market. Five alternative specifications of breeding inventory have been tested as determinants of lamb slaughterings. Each option is evaluated in terms of how well the set of endogenous variables could be simulated under dynamic validation. Particular emphasis is placed on how different breeding inventories affected decision-makers' ability to respond to prices. As well, the effects of an exogenous shock on the predictions from the model are examined.

Modelling Livestock Breeding Inventories

The main objective in developing this livestock model is to identify the sequence of market decisions, and to quantify the relative importance of the factors which underlie them. When specifying such a model, the breeding relationships need to be emphasised because of their critical influence on the production, consumption and price processes. In most instances, the breeding inventory is defined in terms of mating intentions, about which producers have varying degrees of flexibility. Biological influences include the existing breeding stock (which embody past breeding decisions), feed availability and seasonal conditions. These mainly affect the time between the decision to breed and the sale of output. For example, the lag associated with Australian yearling beef production is about 25 months, comprising a two month joining, a nine month gestation and a fourteen month growth period. Regular and irregular phases of the pasture growth and seasonal cycles also influence annual breeding patterns.

Biological influences constrain the ability of producers to adapt production plans to changing market conditions. Accordingly, livestock breeding decisions, rather than livestock output decisions, might be expected to be more responsive to economic factors such as relative price expectations. However, the research noted above has found that these decisions too are unaffected by changes in prices or in producers' expectations. This suggests that changes in inventory are independent of economic influences, and thus are primarily determined by the biological lags underlying the livestock breeding and pasture-seasonal cycles. Including these lags accurately in a model should make it more useful for market analysis.

The choice of specifications to use in the inventory of breeding stock is limited by the periodicity of data and by the inadequate distinction between categories within a livestock species. In the first instance, the highly seasonal behaviour of some livestock markets requires that models ought to be based on frequent observations to capture better the nature of inventory changes and their subsequent market effects. Because data recorded annually (e.g., at March 31 in Australia) are likely to disguise the true nature of these changes, the use of non-annual models requires manipulation of the data to construct an inventory series which is representative. This practice increases the likelihood of errors in measurement. In the second instance, data on breeding inventory are often insufficiently disaggregated, and outputs cannot be attributed to individual breeds within a livestock species. Freebairn (1973) encountered this problem when analysing supply and inventory response for cattle and sheep production in New South Wales.

A model of the Australian prime lamb market

The specification details of a structural econometric model of the Australian lamb market (constructed by Vere, Griffith and Bootle, 1993) are reported in Table 1. The model comprises four blocks representing breeding intentions, production, consumption and price formation. It has a block-recursive structure in which the breeding inventories recursively enter the simultaneously determined production, demand and price blocks. The blocks contain 13 endogenous variables. These are represented by six behavioural equations (breeding intentions to the three main ram breeds, slaughterings, per capita consumption and net exports), and seven identities (two adjusted composite breeding inventories, production, domestic demand, retail price, total lamb industry revenue and exports). Lamb supply and demand are linked by a market clearing condition which determines the equilibrium saleyard price.[1]

In this model, the lagged dependent variables were found to be highly significant, and decisions to breed from the dominant short wool and long wool rams were largely unresponsive to changes in the real farm prices for lamb, wool and wheat.[2] While these results were consistent with those

[1] The general structure of the model is:

(1) $Y_t = Y_{t-1}\Pi_1 + Z_t\Pi_2 + u_t$

where Y_t is a row vector of endogenous variables, Z_t is a row vector of exogenous variables, Y_{t-1} are the lagged endogenous variables, u_t is a row vector of disturbances, and Π_1 and Π_2 are the coefficient matrices.

[2] The lack of price response in these two equations resulted despite the specification of prices as ratios to overcome the high collinearity between the farm price variables which was indicated from preliminary estimation. Another reason for specifying prices as ratios was the belief that lamb producers respond more to changes in farm price relativities because of the (general) joint-product nature of Australian lamb production.

TABLE 1
Structural Econometric Model of the Australian Prime Lamb Market: Specification Details

Block	Dependent Variable		Explanatory Variables
Inventory	INSWAU	f	$INSWAU_L$, $PALBAU_L/PFWLAU_L$, $PALBAU_L/PFWHAU_L$, $PIAU_L$, $DUMDRT_L$
	INLWAU	f	$INLWAU_L$, $PALBAU_L/PFWLAU_L$, $PALBAU_L/PFWHAU_L$, $PIAU_L$, $DUMDRT_L$
	INCPAU	f	$INCPAU_L$, $PALBAU_L/PW27R_L$, $PALBAU_L/PFWHAU_L$, $PIAU_L$, $DUMDRT_L$
	AUSBX	=	δ^{SW} INSWAU + δ^{LW} INLWAU + δ^{CP} INCPAU + $(1-\delta^{LW})$ $INLWAU_L$ + $(1-\delta^{CP})$ $INCPAU_L$
	AUSBI	=	(AUSBX(−1) + AUSBX(−2) + AUSBX(−3) + AUSBX(−4))/4
Production	PDLBAU	=	SLLBAU * WTLBAU
	SLLBAU	f	$AUSBI_L$, $SLLBAU_L$, PIAU, $PW27R_L$
Demand	DCLBAU	f	YPCAU, PRLBAU, PRBFAU, PRPKAU, PRCHAU, DUM74
	DMLBAU	=	DCLBAU * POPNAU
	NEXLBAU	f	PDLBAU, $EXPCE_L$, $CSTLBA_L$, DUM74
Price	PALBAU	=	PDLBAU + $CSTLBA_L$ − DMLBAU − NEXLBAU − CSTLBA
	PRLBAU	=	PALBAU + MMLBAU
	TREV	=	PDLBAU * PALBAU

Notes:
Constant terms, seasonal dummy variables and time trends omitted; $_L$ = lagged variable; variables are defined in Tables A3 and A4.

of several other related studies, they have the potential to introduce problems in model simulations. Specifically, the high values of the lagged dependent variables and the weak price effects mean that the simulated values are likely to be more stable than the actual data, and that the simulation may not regain equilibrium, or take a long time to do so, if an exogenous shock is imposed.

Lamb inventory specification options

In an ideal situation, inventory relationships for breeding livestock would be specified as a set of identities, in which the closing inventory is defined as the opening inventory, minus deaths and slaughterings, plus additions to the breeding base (Griffith and Goddard 1985). Behavioural equations would then be estimated for those components which are most affected by economic influences, such as the culling of aged breeding stock and their replacement by young animals. This would allow the economic factors affecting these decisions to be formally incorporated into the inventory identity. Such a definition applies where data are available on the components of the identity, such as breeding stock slaughterings and the numbers promoted for breeding. However, as there are no records of either of these variables for Australian breeding ewes, opening and closing inventories cannot be defined and have to be estimated from behavioural equations. Other studies in the Australian lamb industries have followed this approach.

In Freebairn's (1973) analysis, the annual breeding inventory for lamb production was defined as the opening inventory of intended matings to all British breed rams (short wool, long wool and Corriedale and Polwarth). With a one-year lag, this inventory was found to be a significant determinant of lamb production. An important limitation noted was that there is no distinction between the types of lambs produced in the data. Griffith and Vere (1981) adopted a similar definition of capacity for Australian lamb production and found that, while the supply and demand sides of the model simulated reality well, the saleyard price variable was poorly reproduced. This was attributed to two factors. The quarterly inventory series was linearly interpolated between the annual data which produced a relatively smooth series, leaving less variation to be captured by the other explanatory variables. This in turn resulted in a stable aggregate breeding inventory, which limited the ability of the model to explain price variations across the range of lambs produced. In neither study were the implications of this inventory definition considered. Most likely, it disguises the dynamics of inventory changes because the types of lambs produced cannot be directly related back to breeding decisions within the individual breeds. This is an important consideration for modelling since Australian lamb production is based on a tiered cross-breeding system which is strongly influenced by the proportions of ram breed and their mating patterns.[3] In a study based on New South Wales, Vere and Griffith (1988) made several adjustments to this variable in an attempt to produce an improved measure of breeding inventory.

In this model, five options are identified for specifying capacity for production of lambs, as determined by the breeding inventories. Three common components were included, which provide a uniform basis for

[3] This system mainly involves joining first-cross ewes (Merinos mated to first-cross rams) to short wool rams to produce the predominant second-cross lamb.

comparing the results of the simulation experiments. The first component follows Jarvis (1974), where the breeding inventory is considered to be a capital stock. Lamb producers react to market price changes by holding stock whenever capital values exceed slaughter values. This assumption has implications for the lag structure used in the model because of the need to represent adequately the temporal links between movements in market prices and outputs of lamb.[4] In the second component, the equations for the aggregate and individual inventory options have similar specifications. Current mating intentions are hypothesised to be determined by the opening breeding inventory, the lagged prices of lamb and other farm products, the area and quality of pastures, and seasonal conditions (these are equations 2.1 to 2.4 in Table 2). The opening breeding inventory is represented by the lagged dependent variable which is also a partial adjustment process since the adjustment of breeding decisions to price changes is likely to be constrained by the biology of the production process. Prices were lagged by eight quarters after prior estimation with other lags produced unsatisfactory results. In the third component, lamb slaughterings are expressed as a function of the lagged breeding inventory for each option, lagged slaughterings, the current area of improved pastures, the lagged price of broad micron wool and the quarterly dummy variables (equations 2.5 to 2.9 in Table 2). Here, slaughterings are considered to respond to price changes indirectly through the inventory equations. This follows Jarvis' capital stock theory in which the rational long-term response of producers to a price rise is to increase production.

The main objectives of the analysis are to investigate the importance of alternative measures of the capital breeding stock in determining current lamb production, and the extent to which such measures inhibit price response in decisions on lamb breeding. This is examined by establishing the effect on the lamb slaughterings function of alternative specifications of breeding inventory and how prices respond to these differences. The extent to which the options and their impacts on slaughterings affect the validity of the model is then examined. As well, the effects of an exogenous shock on the simulation results for each model are determined. All variables in the model are defined and their sources given in Tables A3 and A4 in the Appendix, while the estimates of the behavioural equation for inventories and slaughterings for each specification option are given in Tables 3 and 4.

Option (i): Aggregated British breed inventory

The specifications used by Freebairn (1973) and Griffith and Vere (1981) are followed in option (i). The ewe breeding inventory is defined

[4] Options based on alternative lag distributions in the breeding inventories were not considered because these are largely predetermined by the biology of the breeding process.

TABLE 2

Equations for the Alternative Breeding Inventory Specifications

Option	Dependent Variable		Equation Number	Explanatory Variables
(i)	INEWBB	f	2.1	INEWBB$_L$, PIAU$_L$, PALBAU$_L$/PFWLAU$_L$, PALBAU$_L$/PFWHAU$_L$, DUMDRT
(ii) to (v)	INSWAU	f	2.2	INSWAU$_L$, PIAU$_L$, PALBAU$_L$/PFWLAU$_L$, PALBAU$_L$/PFWHAU$_L$, DUMDRT
(ii) to (v)	INLWAU	f	2.3	INLWAU$_L$, PIAU$_L$, PALBAU$_L$/PFWLAU$_L$, PALBAU$_L$/PFWHAU$_L$, DUMDRT
(ii) to (v)	INCPAU	f	2.4	INCPAU$_L$, PIAU$_L$, PALBAU$_L$/PFWLAU$_L$, PALBAU$_L$/PFWHAUL, DUMDRT
(i)	SLLBAU	f	2.5	INEWBB$_L$, SLLBAU$_L$, PW27R$_L$, DUMDRT$_L$, DUMQ1, DUMQ2, DUMQ3
(ii)	SLLBAU	f	2.6	INEWAU$_L$, SLLBAU$_L$, PW27R$_L$, DUMDRT$_L$, DUMQ1, DUMQ2, DUMQ3
(iii)	SLLBAU	f	2.7	TOTEWE$_L$, SLLBAU$_L$, PW27R$_L$, DUMDRT$_L$, DUMQ1, DUMQ2, DUMQ3
(iv)	SLLBAU	f	2.8	AUSBX$_L$, SLLBAU$_L$, PW27R$_L$, DUMDRT$_L$, DUMQ1, DUMQ2, DUMQ3
(v)	SLLBAU	f	2.9	AUSBI$_L$, SLLBAU$_L$, PW27R$_L$, DUMDRT$_L$, DUMQ1, DUMQ2, DUMQ3

as the aggregate ewe matings to British breed rams. Here, the inventory variable (INEWBB in equation 2.1 in Table 2) comprises the total mating intentions to British breed short wool, long wool, and Corriedale-Polwarth rams. This variable is lagged four quarters and included in the lamb slaughterings equation (2.5). Under this option, the aggregate inventory is the sole endogenous variable in the model's breeding block, and is defined as:

(2) INEWBB = INSWAU + INLWAU + INCPAU.

where the right-hand side exogenous variables are defined as the opening inventories of intentions to mate British breed short wool, long wool and Corriedale-Polwarth rams, respectively.

Option (ii): Disaggregated British breed inventories

In option (ii), separate inventories are specified for the mating intentions to short wool, long wool and Corriedale-Polwarth rams to capture the composition and distribution of the Australian lamb breeding inventory, after the observation that the producers of these breeds respond differently to changes in pastoral conditions and the returns to competitive enterprises (Reynolds and Gardiner 1980). Here, the aggregate breeding inventory is decomposed into three equations to explain matings to the three major British breed categories to produce the aggregate inventory (INEWAU). This inventory is then incorporated into the alternative lamb slaughterings function with a four quarter lag (equation 2.6). This specification gives four endogenous variables in the model's breeding block (equations 2.2, 2.3 and 2.4 and 2 above) where the right-hand side variables are now endogenous.

Option (iii): Disaggregated British breed inventories in a total ewe inventory

In option (iii), the contributions of Merino ram joinings to total lamb slaughterings are incorporated since a significant proportion of slaughter lambs in South and Western Australia are derived from Merinos. Decisions about Merino joinings have a greater flexibility than those involving the British breeds because Merinos have a predominant wool production purpose, and Merino producers can readily respond to increases in lamb prices by culling more lambs than normal. Under this option, equations (2.2), (2.3) and (2.4) are retained and incorporated with the exogenously determined inventory based on Merino rams (INMEAU), to form an identity for the total number of breeding ewes, (TOTEWE) as an alternative endogenous variable in the breeding block:

(3) TOTEWE = INSWAU + INLWAU + INCPAU + INMEAU.

This variable is lagged four quarters and incorporated into the alternative lamb slaughterings function (equation 2.7).

TABLE 3

Equation Estimates for the Alternative Breeding Inventory Specifications: 1969:1 to 1990:4

Dependent Variable	Equation Estimates
3.1 INEWBB (OLS–AR1)	2260.3 + 0.90 INEWBB(–1) – 530.17 PALBAU(–8)/PFWLAU(–8) + 191.5 PALBAU(–8)/PFWLAU(–8) (0.8) (7.4) (–0.8){–0.1/–1.1} (0.5){0.06/0.65} Adj. R^2 = 0.83; h = na; SEE = 0.063; Rho = 0.8 (4.3); N = 87; CV for INEWAU = 0.127
3.2 INSWAU (OLS–AR1)	2191.8 + 0.84 INSWAU(–1) – 370.1 PALBAU(–8)/PFWLAU(–8) + 108.3 PALBAU(–8)/PFWHAU(–8) (0.2) (1.2) (–1.0){–0.04/–0.29} (0.4){0.02/0.15} Adj. R^2 = 0.70; h = na; SEE = 0.073; Rho = 0.8 (1.2); N = 87; CV for INSWAU = 0.097
3.3 INLWAU (OLS–AR1)	310.4 + 0.94 INLWAU(–1) – 97.7 PALBAU(–8)/PFWLAU(–8) + 50.5 PALBAU(–8)/PFWHAU(–8) (0.9) (17.2) (–0.4){–0.03/–0.4} (0.4){0.02/0.4} Adj. R^2 = 0.87; h = 0.817; SEE = 0.07; Rho = 0.7 (6.8); N = 87; CV for INLWAU = 0.249
3.4 INCPAU (OLS–AR1)	317.4 + 0.92 INCPAU(–1) – 462.6 PALBAU(–8)/PW27R(–8) + 166.1 PALBAU(–8)/PFWHAU(–8) (2.6) (30.4) (–2.1){–0.12/-1.55} (2.1){0.11/1.38} Adj. R^2 = 0.95; h = 0.49; SEE = 0.045; Rho = 0.6 (5.9); N = 87; CV for INCPAU = 0.269
3.5 INSWAU (OLS–AR1)	3.6 + 0.99 INSWAU(–4) – 608.6 PALBAU(–8)/PFWLAU(–8) + 327.0 PALBAU(–8)/PFWHAU(–8) + 131.7 DUMDRT(–8) (0.02) (86.3) (–1.5){–0.08/–7.6} (1.5){0.17/15.6} (1.6) Adj. R^2 = 0.99; h = –0.70; SEE = 0.106; Rho = 0.26 (2.4); N = 88; CV for INSWAU = 0.696
3.6 INLWAU (OLS–AR1)	–463.5 + 0.95 INLWAU(–4) – 304.0 PALBAU(–8)/PFWLAU(–8) + 114.8 PALBAU(–8)/PFWHAU(–8) + 19.8 PIAU(–8) (–0.9) (72.0) (–1.4){–0.08/–1.7} (0.9){0.05/1.1} (1.1){0.35/6.9} Adj. R^2 = 0.98; h = –1.19; SEE = 0.179; Rho = 0.5 (5.3); N = 88; CV for INLWAU = 0.554
3.7 INCPAU (OLS)	70.0 + 0.96 INCPAU(–4) – 687.6 PALBAU(–8)/PW27R(–8) + 165.1 PALBAU(–8)/PFWHAU(–8) – 68.5 DUMDRT(–8) (0.8) (91.0) (–3.0){–0.18/–4.4} (2.5){0.12/2.9} (–2.3) Adj. R^2 = 0.98; h = 0.243; SEE = 0.111; N = 88 ; CV for INCPAU = 1.117

Notes:

Figures in ( ) are *t*-values; figures in { \ } are short and long term elasticities; CV = coefficient of variation.

TABLE 4

Equation Estimates for the Alternative Lamb Slaughterings Specifications: 1969:1 to 1990:4

Dependent Variable	Equation Estimates
4.1 SLLBAU (OLS)	1.4 + 0.00006 INEWBB(–4) + 0.6 SLLBAU(–4) – 0.007 PW27R(–1) – 0.3 DUMQ1 – 0.3 DUMQ2 – 0.09 DUMQ3 (4.1) (4.8){0.34/0.86} (7.8) (–8.2){–0.19/–0.4} (–2.6) (–2.7) (–0.9) Adj. R^2 = 0.77; h = 1.43; SEE = 0.074; N = 84; CV on INEWBB = 0.144
4.2 SLLBAU (OLS)	1.0 + 0.00006 INEWAU(–4) + 0.6 SLLBAU(–4) – 0.007 PW27R(–1) – 0.3 DUMQ1 – 0.3 DUMQ2 – 0.09 DUMQ3 (4.1) (4.8){0.34/0.86} (7.8) (–8.2){0.19/0.48} (–2.6) (–2.7) (–0.7) Adj. R^2 = 0.77; h = 0.99; SEE = 0.074; N = 84; CV on INEWAU = 0.127
4.3 SLLBAU (OLS)	–0.21 + 0.00006 TOTEWE(–4) + 0.4 SLLBAU(–4) – 0.005 PW27R(–1) – 0.4 DUMQ1 – 0.5 DUMQ2 – 0.2 DUMQ3 (–0.4) (6.2){0.92/1.53} (5.1) (–6.4){–0.14/–0.23} (–3.8) (–4.1) (–1.6) Adj. R^2 = 0.80; h = 0.74; SEE = 0.068; N = 84; CV on TOTEWE = 0.074
4.4 SLLBAU (OLS)	1.1 + 0.0003 AUSBX(–4) + 0.6 SLLBAU(–4) – 0.009 PW27R(–1) – 0.4 DUMQ1 + 0.5 DUMQ2 – 0.1 DUMQ3 (3.1) (5.9){0.55/1.36} (5.3) (–9.4){–0.23/–0.62} (–3.7) (3.7) (–1.4) Adj. R^2 = 0.79; h = 0.73; SEE = 0.07; N = 84; CV on AUSBX = 0.523
4.5 SLLBAU (OLS)	1.1 + 0.0003 AUSBI(–4) + 0.4 SLLBAU(–4) – 0.008 PW27R(–1) – 0.4 DUMQ1 – 0.5 DUMQ2 – 0.1 DUMQ3 (3.1) (5.9){0.54/0.92} (5.3) (–9.4){–0.22/–0.36} (–3.7) (–3.7) (–1.4) Adj. R^2 = 0.79; h = 0.79; SEE = 0.07; N = 84; CV on AUSBI = 0.096

Notes:
Figures in ( ) are *t*-values; figures in { \ } are short and long term elasticities; CV = coefficient of variation.

Option (iv): Disaggregated British breed inventories in an adjusted total ewe inventory

Under this option (iv), the individual inventories (as specified under option (iii)), are adjusted to accommodate their contributions to total lamb production and the time lags between the decisions to breed and lamb output. The influence of the inventory composition is recognised here since each ram breed contributes different proportions of their progeny to total lamb output. Short wool rams (mainly Poll Dorsets) make up nearly 60 per cent of Australian matings with all progeny becoming available for slaughter immediately after weaning. This process involves approximately an eleven month lag (joining, gestation and weaning) between breeding decisions and lamb output. Long wool matings (usually Border Leicester rams to Merino ewes) produce first-cross progeny with most of the females being retained for second-cross breeding, and the males becoming available for slaughter after weaning in about the same time as the second-cross lambs. The ewes retained from the long wool joinings produce lambs some three years hence when they mature and are mated. This latter situation holds for the other closed breeds which include the Corriedales and Polwarths.

Equation (4) represents the contributions to production of the individual ram breeds, adjusted for quarterly production lags, with a five per cent mortality deduction for each progeny type. This inventory variable (AUSBX) is lagged four quarters to be consistent with its lag structure, and is included in the alternative function for lamb slaughterings (equation 2.8):

$$(4) \quad AUSBX = \delta^{SW} INSWAU + \delta^{LW} INLWAU + \delta^{CP} INCPAU + (1-\delta^{LW}) INLWAU_L + (1-\delta^{CP}) INCPAU_L$$

where, δ^{SW}, δ^{LW}, and δ^{CP} are the slaughterings contributions adjustments for short wool, long wool and Corriedale-Polwarth rams, here, specified as 0.95 for short wools, 0.55 for long wools and 0.60 for Corriedales and Polwarths, and $_L$ is a lag of eight-quarters.

Option (v): Disaggregated British breed inventories in an adjusted total ewe inventory allocated on a quarterly basis

As data on mating intentions are only collected annually (each March 31), it is necessary to derive a quarterly series to represent the seasonal allocation of mating intentions across the three ram breed categories. The approach previously adopted of linearly interpolating the data between the annual values (as done for options (i) to (iv)) imposed regularity in the constructed series which introduced autocorrelation problems (Griffith and Vere 1981). In option (v), this approach was refined by seasonally allocating the breeding intentions according to the opinions of lamb industry experts within NSW Agriculture. For each category, most matings occur in the first quarter for lambing in Spring, with a significant proportion mated in quarter three for lambing in the following Autumn.

Breeding intentions for the second and fourth quarters are typically low. From these observations, the quarterly breeding intentions for quarter 1 (spring lambing) to 4 are allocated as 0.50, 0.05, 0.30 and 0.15 for short wools; as 0.40, 0.05, 0.30 and 0.25 for long wools, and as 0.70, 0.05, 0.20 and 0.05 for Corriedale-Polwarth ram breeding intentions, respectively.[5] This gives a seasonally adjusted breeding inventory (AUSBI) which incorporates the seasonal allocation of mating intentions:

(5) AUSBI = (AUSBX(–1) + AUSBX(–2) + AUSBX(–3) + AUSBX(–4))/4.

The quarterly allocation of breeding intentions is equated in this identity to the annual March 31 estimate, and is lagged four quarters and included in the alternative lamb slaughterings function (equation 2.9). Equations (4) and (5) therefore represent the constraints on lamb breeding decisions which are based on the assumptions about the nature of the biological lags involved.

Methods

The base model defined in Table 1 was estimated from quarterly data between 1969:1 to 1990:4 using the TSP (Version 4.1C) econometric package. The three breeding inventories and the lamb slaughterings equations were estimated by OLS, while those equations containing current period endogenous variables as regressors (lamb exports and per capita lamb consumption) were estimated by 2SLS. All equations were corrected for first-order autocorrelation where necessary, and the complete model was validated under a dynamic routine over the same estimation sample period. Because this process utilises the solved rather than the actual values of the lagged endogenous variables, it provides a more demanding evaluation of model validation. For example, simulation errors will be compounded throughout the model.

For the simulation experiments, the estimated equations from Tables 3 and 4 were incorporated into the base model and subjected to the same simulation procedures as for that model. The differences in each experiment related only to the effects on the breeding inventory and slaughterings alternatives (while the remaining equations in the model remained unchanged). Each model based on the inventory options was then displaced by an exogenous shock to examine the time taken to regain equilibrium. To reflect the impact of an external shock, such as the suspension of the wool price support scheme in February 1991, the values of the two wool price variables were reduced by 30 per cent over the 20 quarter period, 1980:1 to 1984:4. The effects of this shock were assessed in terms of its impact on the lamb saleyard price variable (PALBAU). Because the values of this variable were determined by a market balance

[5] These factors were based on specialist lamb industry opinion within NSW Agriculture, and can be readily varied within the model.

identity, it was considered that it would more readily reflect errors resulting from the model simulation processes. These impacts were calculated from the percentage differences between the predicted price series generated by the model and simulations for each option.

Results and Discussion

Tables A1 and A2 in the Appendix contain the base model's estimation and validation results (these are fully described in Vere *et al.* 1993). Tables 3 and 4 contain the estimated equations for the specification options, the coefficients of variation for each inventory series (in Table 3), and the same statistics for the corresponding slaughterings functions (in Table 4). The estimates indicate the significant influence of the lagged inventories and the generally low price response in lamb breeding decisions. In each inventory equation (except for the short wool inventory with the one-quarter lag in equation 3.2) the lagged dependent variables explain much of the variation in current breeding decisions. This is particularly so in equations 3.5 to 3.7 incorporating four-quarter lags on the dependent variables, which were considered to more accurately represent the biological constraints in lamb production, i.e., breeding decisions in the previous fourth quarter commit producers to lamb production over at least the following four quarters. The pasture and seasonal variables were omitted from equations 3.1 to 3.4 because, contrary to expectations, they were found to be insignificant determinants of breeding decisions. Overall, the results demonstrate the status of the existing breeding flock as capital stock under which variations in past breeding decisions are readily transmitted into current breeding decisions.

Three issues need to be considered in interpreting the price response results. First, because of the size of the lagged dependent variables and the adjustments made to the base data for the inventory variables, these equations should be considered as estimating the annual changes in lamb breeding intentions rather than of their levels at any time. Second, the elasticities were derived from constructed price ratios and these are not strictly comparable to elasticities derived from linear price coefficients. Third, the coefficients of variation indicate the relative stability of the individual inventory series and thus the levels of variation which might be explained by variables other than the lagged inventories. Here, it is expected that a more variable inventory series would exhibit greater price response than one with low variation.

Given these qualifications, there is less consistency in the impact of farm price changes on lamb breeding decisions across the inventory categories. The equations for the aggregate inventory (equation 3.1) and for the dominant short and long wools (equations 3.2 and 3.3) where the dependent variable is lagged one-quarter, display minimal price effects. The low short-term elasticities indicate a weak response in breeding intentions to price changes. These effects are consistent with the much larger longer-term price elasticities and result from the low variability in these series. The exception is the Corriedale-Polwarth inventory (equation 3.4) in which stronger price effects and more elastic price response on both the short and longer terms are evident. One explanation for this is that Corriedale-Polwarth producers have greater flexibility in production than others because of the dual purpose nature of this breed.

Both price significance and price response are considerably greater in equations 3.5 to 3.7 in which the lagged dependent variables have four-quarter lags. Although the short-term elasticities are also low, the longer-term estimates are much larger and indicate higher price responsiveness in each inventory. The most likely explanation is that the higher variation in the disaggregated and adjusted (discontinuous) breeding intentions series allows for more variation in the current inventory to be explained by variables other than previous breeding decisions.

The estimated functions for lamb slaughterings (Figure 1) corresponding to the specification options for each inventory (Table 4) are more consistent across the options. Each of the alternative production capacity variables has similar explanatory power, and the effects of lagged slaughterings and coarse wool prices are consistent across each equation. However, lamb slaughterings respond more to changes in the disaggregated and adjusted inventories than to the aggregated specifications, indicating that the latter options provide an improved measure of the capacity of the market to produce lambs.

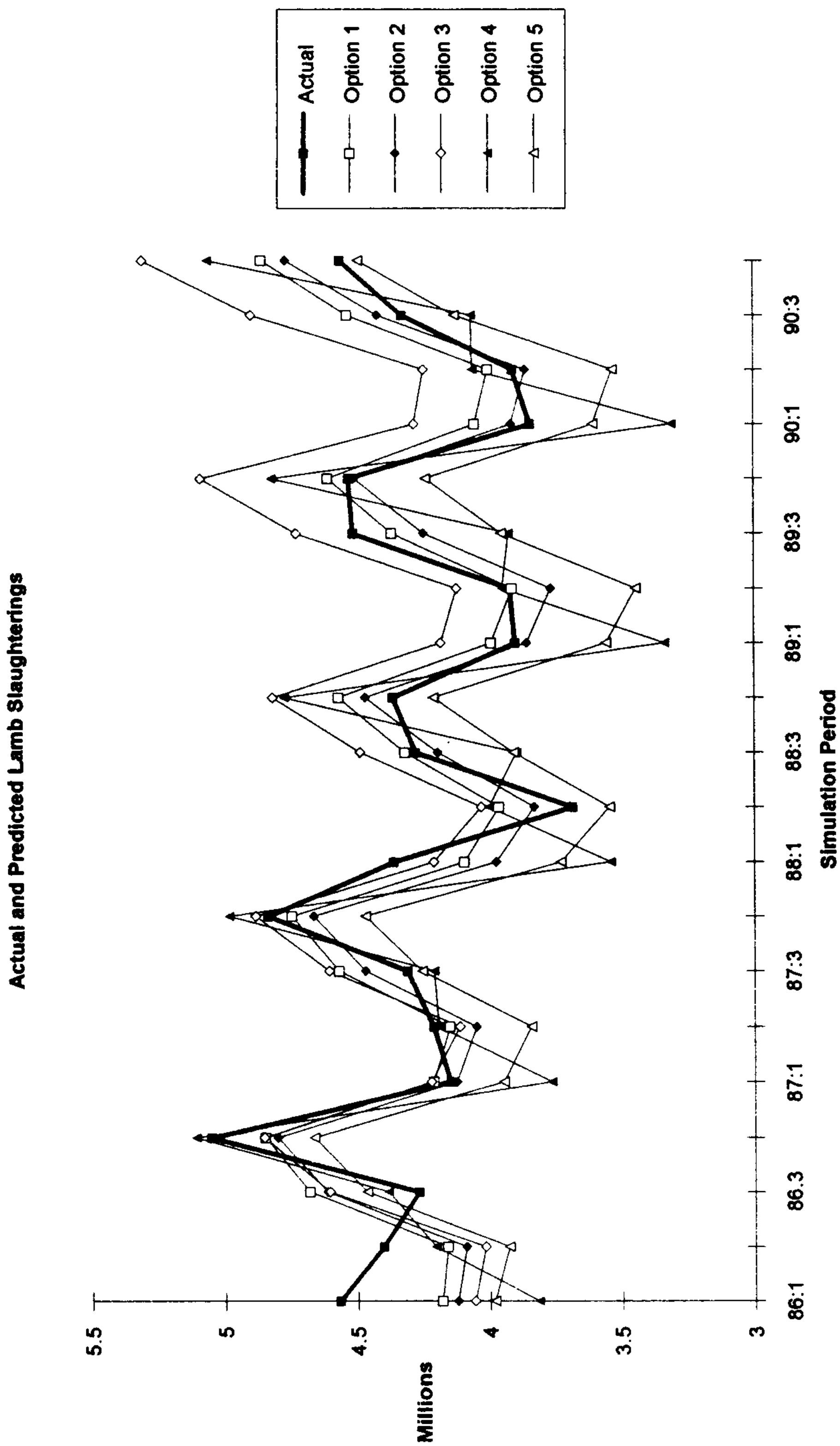
The main modelling differences with the breeding inventory specification options become apparent when the individual models were simulated (Table 5) using historical data. In the first option, the aggregate inventory provides the least satisfactory explanation of quarterly variation in breeding decisions, with a relatively low simulation R^2. The actual on predicted coefficient indicates that the predicted inventory series is substantially more stable than the actual data.[6] The remaining endogenous variables simulate actual events reasonably well, although the predicted saleyard and total revenue series are considerably less stable than the actual series because of the influence of the stable predicted inventory series in forcing saleyard prices to over-adjust to regain equilibrium. Disaggregating the inventory into its breed components (option (ii)) and including Merino matings in the inventory as in option (iii), provides some improvements, but overall, the inventory blocks do not simulate the structural equation estimates well. The high actual on predicted coefficients on the short wool inventories under these options indicate that the predicted series are much more stable than the actual data which causes simulation problems for the rest of the model. The simulation results improve when the inventory data are disaggregated and adjusted to incorporate the components of production contributed by the three ram breeds and the time lags between breeding decisions and lamb output (option (iv)). Further improvements

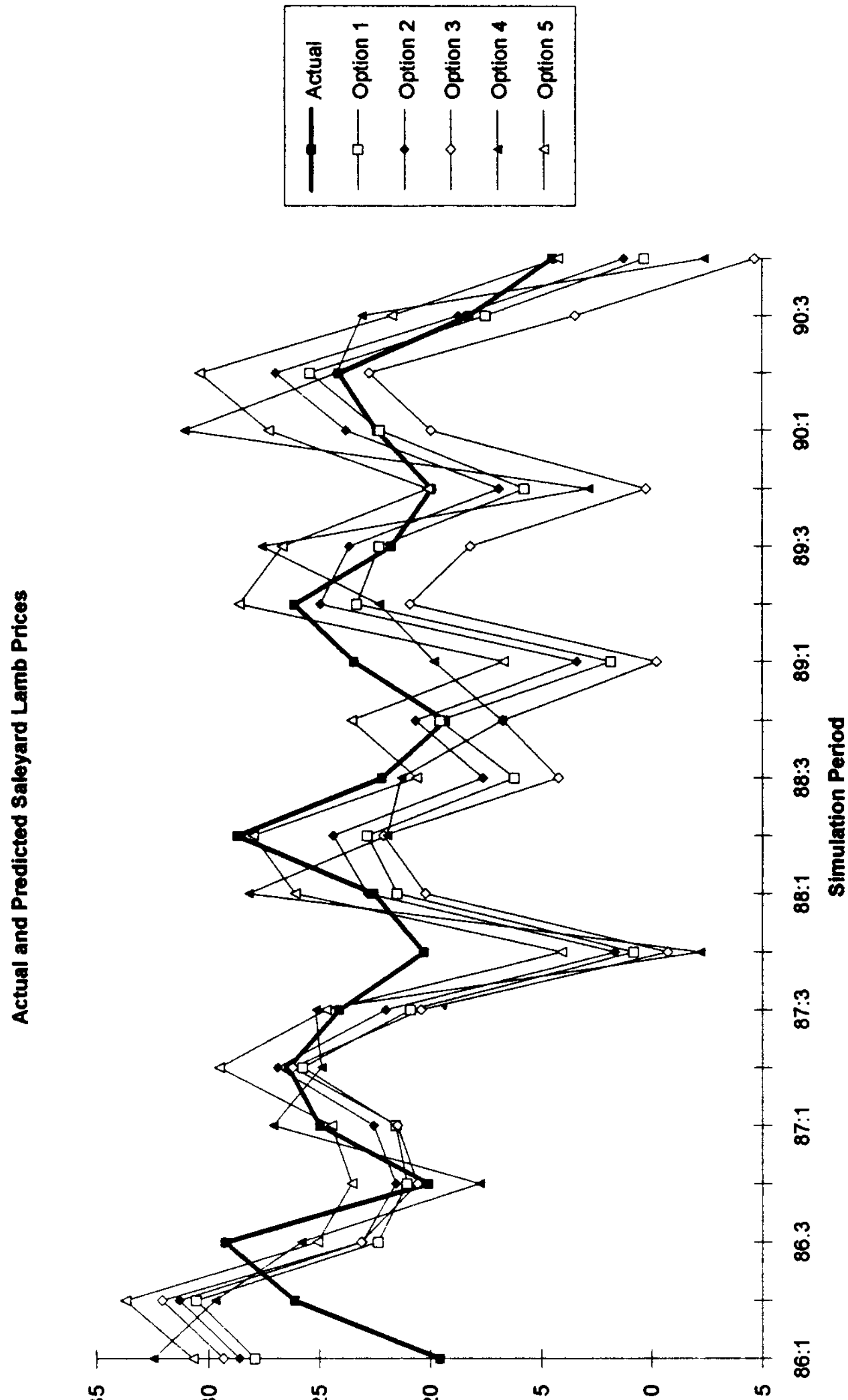
[6] The simulation R^2 is a measure of the ability of the model to explain variations in the actual data when the current period interactions between the simultaneously determined endogenous variables and the dynamic interactions of all the lagged endogenous variables are considered together.

TABLE 5

Dynamic Validation of the Alternative Breeding Inventory Specifications: 1969:1 to 1990:4

Endogenous Variable	Squared Correlation Coefficients					Coefficients of Actual on Predicted				
	(i)	(ii)	(iii)	(iv)	(v)	(i)	(ii)	(iii)	(iv)	(v)
INSWAU		0.48	0.45	0.97	0.98		2.31	2.78	1.02	1.03
INLWAU		0.46	0.46	0.89	0.90		1.15	1.14	1.00	1.03
INCPAU		0.66	0.68	0.96	0.96		0.99	0.98	0.92	0.92
INEWAU	0.38	0.59				0.70	1.42			
AUSBX				0.97	0.98				1.01	1.01
AUSBI					0.77					0.94
TOTEWE			0.77					0.80		
SLLBAU	0.81	0.77	0.66	0.62	0.71	0.99	1.08	0.89	0.86	0.99
PDLBAU	0.80	0.76	0.65	0.60	0.70	1.00	1.07	0.84	0.84	1.03
DCLBAU	0.81	0.80	0.72	0.69	0.79	1.02	1.22	1.09	1.04	1.06
DMLBAU	0.69	0.65	0.52	0.50	0.65	0.96	1.10	0.80	0.85	1.15
PALBAU	0.77	0.75	0.75	0.71	0.72	0.79	0.77	0.69	0.71	0.84
PRLBAU	0.80	0.78	0.75	0.69	0.78	0.89	0.93	0.80	0.86	0.97
TREV	0.80	0.82	0.80	0.81	0.81	0.84	0.79	0.71	0.76	0.83
NEXLBAU	0.60	0.59	0.59	0.53	0.48	0.96	0.88	0.87	0.75	0.76


Actual and Predicted Lamb Slaughterings
Actual
Option 1
Option 2
Option 3
Option 4
Option 5
Millions
5.5
5
4.5
4
3.5
3
86:1
86:3
87:1
87:3
88:1
88:3
89:1
89:3
90:1
90:3
Simulation Period


Actual and Predicted Saleyard Lamb Prices
Actual
Option 1
Option 2
Option 3
Option 4
Option 5
35
30
25
20
15
10
5
86:1
86:3
87:1
87:3
88:1
88:3
89:1
89:3
90:1
90:3
Simulation Period

result from the inclusion of an additional adjustment representing the seasonal allocation of lamb breeding intentions across the ram breeds (option (v)). Of these two latter options, option (v) results in a much better simulation of the remaining endogenous variables in the model.

TABLE 6
Simulated Impact of a 30 Per Cent Wool Price Reduction on Lamb Saleyard Price: 1980:1 to 1984:4 (% change in PALBAU)

	Breeding Inventory Specification Options				
	(i)	(ii)	(iii)	(iv)	(v)
1981:1	–6.9	–7.3	–5.1	–6.8	–7.7
1982:1	–12.6	–14.0	–7.9	–12.3	–12.7
1983:1	–16.7	–20.3	–9.1	–14.8	–15.4
1984:1	–16.8	–20.4	–7.6	–13.1	–12.7
1985:1	–18.1	–23.5	–8.4	–11.5	–9.8
1986:1	–7.3	–18.7	–6.0	–7.1	–4.3
1987:1	–3.3	–22.7	–7.6	–5.6	–0.9
1988:1	–0.3	–23.1	–9.7	–4.3	1.0
1989:1	1.5	–37.9	–22.4	–3.8	5.3
1990:1	1.0	–21.3	–10.1	0.7	4.7
A/P coefficients for PALBAU[a]					
(i) no shock	0.77	0.81	0.72	0.72	0.84
(ii) with shock	0.75.	0.70	0.71	0.70	0.83

[a] A/P = coefficient of actual on predicted

When expressed through differences in predicted saleyard prices, the results of the impact simulations (Table 6) confirm the anticipated simulation problems associated with the strong lagged dependent variables in the inventory equations (Section 2.1). Under all options, predicted lamb prices (Figure 2) are considerably affected by the imposition of a shock over the following 20 quarters. Options (ii) and (iii) which have very stable predicted series for the short wool inventory are most affected and do not regain equilibrium ten years after the shock. In particular, option (ii) remains well off track and predicts prices more than 20 per cent below predicted values of the non-impact simulation 40 quarters later. The large reduction in the actual on predicted coefficient on the saleyard price variable demonstrates the influence of the very stable short wool inventory in preventing the adjustment of prices following the shock. The differences in actual and predicted prices associated with option (iii) are initially smaller than under option (ii) but these have increased considerably by the end of the model validation period. Options (iv) and (v), based on the disaggregated and adjusted inventories, also display significant differences in predicted prices over the first four years, but these effects quickly diminish thereafter as the simulations regain equilibrium. The stability of the predicted saleyard price series is greater under option (v). While the first options based on the aggregate inventory also displayed an ability to regain equilibrium, it has a relatively poor validation performance in its inventory block.

Summary

In this analysis, the effects of alternative ewe breeding inventory specifications on the validity of a structural econometric model of the Australian prime lamb market have been investigated. Particular attention has been given to the issue of price response in breeding decisions and to the ability of the model to cope realistically with exogenous shocks. Earlier related work indicated the potential for problems to arise in model simulation because of the strong influence of the lagged dependent variables in the inventory functions and the extent to which these effects inhibited price response.

The main result is that adopting a disaggregated approach in modelling livestock breeding inventories has been shown to provide useful information. The estimates were substantially improved when disaggregated and seasonally allocated data were used to estimate the lamb breeding inventories and the latter were incorporated into the lamb slaughterings function. This approach improved the simulation of the breeding block and allowed for greater price response in current lamb breeding decisions. In comparison, specifications based on the disaggregated but unadjusted inventories had poor simulation results for their breeding blocks in comparison. There were also indications of problems with the stability of the model simulation and these were confirmed when an exogenous shock was imposed. Those options incorporating both disaggregated and adjusted data were able to adjust more quickly to a shock because breeding decisions were more responsive to price changes (particularly in the longer term) and were less predetermined by previous breeding decisions. This study has confirmed the prognosis of Reynolds and Gardiner (1980), who called for greater disaggregation in livestock inventory modelling, and has taken the disaggregation procedures further.

References

Arzac, E. R. and Wilkinson, M. (1979), 'A quarterly econometric model of the United States livestock and feed grains markets and some of its policy implications', *American Journal of Agricultural Economics* 61, 297-308.

Fisher, B. S. and Munro, R. G. (1979), 'Supply response in the Australian extensive livestock and cropping systems: a study of intentions and expectations', *Australian Journal of Agricultural Economics* 27, 1-11.

Freebairn, J. W. (1973), 'Some estimates of supply and inventory response functions for the cattle and sheep sector of New South Wales', *Review of Marketing and Agricultural Economics* 41, 53-90.

Griffith, G. R., and Goddard, E. W. (1985), *An Annual Econometric Model of the Australian Beef Industry: Revised 1985,* N.S.W. Department of Agriculture, Division of Marketing and Economics: Research Workpaper No. 7/85.

Griffith, G. R. and Vere, D. T. (1981), *A Quarterly Econometric Model of the Australian Prime Lamb Market,* Department of Agriculture New South Wales, Division of Marketing and Economics: Research Workpaper No. 3/81.

Jarvis, L. S. (1974), 'Cattle as capital goods and ranchers as portfolio managers: an application to the Argentine cattle sector', *Journal of Political Economy* 83, 489-420.

Kulshreshtha, S. N. and Wilson, A. G. (1972), 'An open econometric model of the Canadian beef cattle sector', *American Journal of Agricultural Economics* 54, 84-91.

Nerlove, M. (1979), 'The dynamics of supply: retrospect and prospect', *American Journal of Agricultural Economics* 61, 874-888.

Reynolds, R. G and Gardiner, B. (1980), 'Supply response in the Australian sheep industry: a case for disaggregation and dynamics', *Australian Journal of Agricultural Economics* 24, 196-209.

Rucker, R. R., Burt, O. R. and LaFrance, J. T. (1984), 'An econometric model of cattle inventories', *American Journal of Agricultural Economics* 66, 131-144.

Tryfos, P. (1974), 'Canadian supply functions for livestock and meat', *American Journal of Agricultural Economics* 56, 107-13.

Vere, D. T. and Griffith, G. R. (1988), 'Supply and demand interactions in the New South Wales prime lamb market', *Review of Marketing and Agricultural Economics* 59, 287-305.

Vere, D. T., Griffith, G. R. and Bootle, B. W. (1993), *The Development and Application of a Quarterly Econometric Model of the Australian Prime Lamb Market,* N.S.W. Agriculture, Economic Services Unit, Agricultural Economics Bulletin (under review).

TABLE A1

Structural Econometric Model of the Australian Prime Lamb Market: Equation Estimates: 1969:1 to 1990:4

Dependent Variable	Equation Estimates
INSWAU (OLS-AR1)	3.6 + 0.99 INSWAU(–4) + 131.7 DUMDRT(–8) – 608.6 PALBAU(–8)/PFWLAU(–8) + 327.0 PALBAU(–8)/PFWHAU(–8) (0.02) (86.3) (1.6) (–1.5){–0.08/–7.6} (1.5) {0.16/15.6} Adj. R^2 = 0.99; h = –0.70; SEE = 0.106; Rho = 0.26(2.4); N = 88
INLWAU (OLS-AR1)	–463.5 + 0.95 INLWAU(–4) + 19.8 PIAU(–8) – 304.0 PALBAU(–8)/PFWLAU(–8) + 114.8 PALBAU(–8)/PFWHAU(–8) (–0.9) (72.0) (1.1) {0.35/6.9} (–1.4) {–0.08/–1.7} (0.9) {0.05/1.1} Adj. R^2 = 0.98; h = –1.19; SEE = 0.179; Rho = 0.5 (5.3); N = 88
INCPAU (OLS)	70.0 + 0.96 INCPAU(–4) – 68.4 DUMDRT(–8) – 687.6 PALBAU(–8)/PW27R(–8) + 165.1 PALBAU(–8)/PFWHAU(–8) (0.8) (91.0) (–2.3) (–3.0){–0.18/–4.4} (2.5) {0.12/2.9} Adj. R^2 = 0.99; h = 0.243; SEE = 0.111; N = 88
SLLBAU (OLS)	1.1 + 0.0003 AUSBI(–4) + 0.4 SLLBAU(–4) – 0.008 PW27R(–1) – 0.4 DUMQ1 – 0.5 DUMQ2 – 0.1 DUMQ3 (3.1) (5.9) {0.55/0.9} (5.3) (–9.4) {–0.22/–0.37} (–3.7) (–3.7) (–1.4) Adj. R^2 = 0.79; h = 0.728; SEE = 0.070; N= 84
DCLBAU (2SLS)	4.3 – 0.07 PRLBAU – 0.002 YPCAU + 0.03 PRBFAU + 0.02 PRPKAU + 0.03 PRCHAU – 0.4 DUMQ1 – 0.4 DUMQ2 – 0.03 DUMQ3 + 0.7 DUM74 (6.2) (–10.7) {–1.5} (–1.6) {–0.22} (11.7) {0.82} (3.6){0.57} (6.2) {0.48} (–3.8) (–3.1) (–0.3) (2.7) Adj. R^2 = 0.91; d = 2.00; SEE = 0.057; N = 88
NEXLBAU (2SLS)	–8.8 + 0.23 PDLBAU + 0.07 EXPCE(–1) + 0.59 CSTLBA(–1) – 1.4 DUMQ1 – 1.1 DUMQ2 – 2.3 DUMQ3 – 4.1 DUM74 (–1.5) (3.3){0.14} (1.6) {0.11} (4.2) {0.01} (–1.3) (–0.8) (–2.8) (–1.7) Adj. R^2 = 0.61; d = 1.96; SEE = 0.358; N = 84

Notes:

All estimates are calculated at the sample means; estimated *t* values are given in ( ); short and long-term elasticities are given in { \ }

TABLE A2

Structural Econometric Model of the Australian Prime Lamb Market: Ex Post Dynamic Validation: 1969:1 to 1990:4

Block	Endogenous Variable	Correlation Coefficient Squared	Root Mean Squared Error (% of mean)	Theil Statistic[a]	% Error Due to Bias	% Error Due to $B \neq 1$	Coefficient of Actual on Predicted
Inventory	INSWAU	0.98	11.1	0.05	0.03	0.07	1.03
Inventory	INLWAU	0.90	19.0	0.07	0.26	0.04	1.02
Inventory	INCPAU	0.97	21.1	0.07	0.09	0.18	0.92
Inventory	AUSBI	0.77	5.0	0.05	0.14	0.01	0.94
Inventory	AUSBX	0.98	7.1	0.07	0.05	0.01	1.01
Production	SLLBAU	0.72	8.0	0.08	0.05	0.00	0.99
Production	PDLBAU	0.70	8.0	0.08	0.05	0.00	1.03
Demand	DCLBAU	0.79	8.1	0.08	0.03	0.01	1.06
Demand	DMLBAU	0.65	8.0	0.08	0.04	0.03	1.15
Demand	NEXLBAU	0.49	26.0	0.25	0.02	0.08	0.76
Price	PALBAU	0.72	17.1	0.17	0.03	0.08	0.84
Price	PRLBAU	0.78	6.0	0.06	0.03	0.00	0.97
Price	TREV	0.81	13.0	0.13	0.03	0.15	0.83

[a] This is Theil's 1961 inequality coefficient.

TABLE A3

Data Definitions and Sources: Endogenous Variables

Variables	Variable Definition	Unit	Source
INEWAU	mating intentions to British breed rams	million	ABS
INSWAU	mating intentions to short wool rams	million	ABS
INLWAU	mating intentions to long wool rams	million	ABS
INCPAU	mating intentions to Corriedale and Polwarth rams	million	ABS
AUSBX	adjusted mating intentions to British breed rams	million	calculated
AUSBI	seasonally adjusted mating intentions to British breed rams	million	calculated
TOTEWE	mating intentions to British breed and Merino rams	million	ABS
SLLBAU	lamb slaughterings	million	AMLC
PDLBAU	lamb production	kt	AMLC
DCLBAU	per capita lamb consumption	kg/head	calculated
DMLBAU	total lamb demand	kt	calculated
PALBAU	real saleyard lamb price	c/kg	ABARE
PRLBAU	real retail lamb price	c/kg	ABARE
NEXLBAU	net lamb exports	tonne	AMLC
TREV	total lamb industry revenue	$ thousand	ABS

TABLE A4

Data Definitions and Sources: Exogenous Variables

Variables	Variable Definition	Unit	Source
AFAU	area of improved pasture fertilised	million ha	ABS
CSTLBA	stocks of lamb, close of quarter, carcase equivalent	kt	AMLC
EXPCE	real export-saleyard lamb price differential	c/kg	calculated
MMLBAU	real price spread for lamb	c/kg	calculated
PFWLAU	real average wool price	c/kg clean	AWC
PRBFAU	real retail price of beef	c/kg	ABARE
PRCHAU	real retail price of chicken	c/kg	ABARE
PRPKAU	real retail price of pork	c/kg	ABARE
PW27R	real average 27 micron wool price	c/kg clean	AWC
PFWHAU	real average export price of wheat	$/tonne	ABARE
PIAU	area of improved pastures	million ha	ABS
POPNAU	Australian population	million	ABS
WAGEAU	real wages paid in meat processing sector	$/week	ABS
WTLBAU	average dressed carcass weight of all lambs slaughtered	kg	AMLC
YPCAU	real per capita household disposable income	$ million	ABS
DUMDRT	dummy variable for periods of drought,		
DUM74	dummy variable for US beef shock, 1974 (4) = 1, 0 elsewhere		

Notes:
DUMQ1, DUMQ2, DUMQ3 are seasonal dummies; TIME is a linear time trend.