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Forecasting in the Australian Lamb Industry: the Influence of Alternate Price Determination Processes

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The purpose of this paper is to evaluate the influence of alternate price determination specifications on the ability of a structural econometric model of the Australian prime lamb industry to accurately forecast saleyard lamb prices. Five variations of this model were specified according to the manner in which the farm prices of lamb were assumed to be determined, and these were used to produce 12 quarterly dynamic price forecasts over 1991:1 to 1993:4. The results confirmed the importance of the assumed nature of the price determination process in influencing the model's solution and its subsequent ability to forecast farm prices. Based on the forecasts' mean squared errors, the preferred specification was one which incorporated a traditional market balance and an exogenously-determined farm-retail price spread. This preference remained following an additional forecast comparison in which the structural models' forecasts were combined with those of an ARIMA model. As such, this price determination specification has been shown to be most applicable to a market such as that for Australian lamb which exhibits relatively small stocks and exports and a stable domestic demand.

1. Introduction

Farm prices are typically the most unstable variables in competitive agricultural markets. The combination of inelastic demands and price spreads which are positively related to output leads to significant price instability. In most of Australia's extensive livestock production systems, there are also strong seasonal patterns in supply due to pasture growth phases and associated breeding cycles. Further, there is evidence of longer term cyclical behaviour because of the relatively long biological lags between production decisions and the delivery of outputs onto the market and the changing expectations of producers during these lags. These factors emphasise the importance of price forecasts in the livestock markets. Freebairn (1975) considered that price forecasts were most relevant to producers because they could be readily translated into income forecasts, while others in the market were more concerned with quantity forecasts because their investment decisions in plant and equipment are based on likely product quantities passing through the mar-

ket. In either case, price forecasts are a major influence in making production decisions.

The question of how price forecasts can best be produced continues to be debated (McIntosh and Dorfman). One observation from the available forecast method comparisons is that broad recommendations cannot be made in all situations, and that the choice of forecast method is problem specific, depending on the forecast user's requirements. Several studies of livestock farm price forecasting have demonstrated the accuracy advantages of using econometric and time-series forecasting models over the non-quantitative methods, and the merits of combining forecasts (Leuthold, MacCormick, Schmitz and Watts; Brandt and Bessler; Bessler and Brandt; Vere and Griffith, 1990). Each of these studies included a structural market model on the expectation that a validated model which explicitly incorporated the major elements of market supply and demand would represent a sound price forecasting mechanism.

An issue which has received relatively little attention in agricultural commodity modelling is the effect of the price determination specification on a model's ability to simulate prices as a basis for price forecasting. Popkin maintained that attempts to improve the price forecasting accuracy of econometric models first required improvements in the specification of the price determination mechanism. However, few of the studies of livestock price forecasting incorporating the use of a structural model have detailed the form of the price determination process involved in the model's specification. Given the range of options for determining prices in structural models, the form of this process can be expected to have a major influence on a model's price simulation and subsequent forecasting performance.

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On the surface, the Australian lamb market appears to be highly competitive with many producers, wholesalers and consumers, and farm prices determined mainly by auction which follow strong seasonal patterns. This suggests that prices are likely to be determined by the balance of supply and demand with largely unconstrained price transmission between the farm and retail markets. However, recent research has shown that there are pricing inefficiencies in the lamb auction market (particularly in regard to price-fat score relationships) and these can be expected to impact on the extent to which this market can be realistically modelled in a competitive context (Mullen). Earlier, Freebairn (1984) found that lamb prices followed different price transmission patterns than other meats, with retail prices "causing" farm prices in the Granger sense. Problems encountered in previous attempts to estimate a 'traditional' competitive specification with an endogenous price-spread (Vere and Griffith 1986), have resulted in this interest in investigating the effects of adopting some of the alternate price determination specifications that have been proposed for other agricultural commodity markets. Because it is difficult *a priori*, to choose what the most appropriate price determination specification might be and given the uncertainty about the true nature of competition in the lamb market, this issue needs to be empirically resolved.

This paper has two objectives. First, the influence of various price determination specifications on the ability of a structural econometric model of the Australian lamb market to simulate the prices received by lamb producers is investigated. Second, farm lamb prices are forecast using models incorporating these price determination options and the results are compared.

2. Price Determination Processes

Model specification influences how well a model solves and hence its usefulness for forecasting and other market analyses. The usual approach adopted in many agricultural commodity models has been to specify structural relationships for production, consumption and stock behaviour and to determine prices through the balance of supply and demand. Using this 'traditional' specification, Labys proposed various options for price determination with choice depending on the length of the data period relative to the market lags, the importance of market stocks and the size of the supply and demand elasticities. In each option, the structure of the price determination mechanism

largely depended on the extent to which prices were influenced by changes in stocks.

Heien considered that this dependence of prices on stocks behaviour reduced the ability of the traditional model to explain the price determination process because the simulated prices were liable to be adversely affected by errors or other problems in the model's component supply and demand equations. Heien's main objection was that the residual nature of stocks made the stocks equation most vulnerable to measurement error, causing the prices so generated to be also subject to error¹. For annual models, a price dependent demand specification was proposed based on the consideration that the annual output of most farm products is largely predetermined and the remaining variation in quantity is in either stocks or demand. If stocks are relatively stable, prices are mainly determined by demand. This argument applies to either retail or farm level demand, and follows Waugh in that price is determined by retail demand, with farm-level demand as a derived demand. Where either farm or retail price was determined under this process, the other price could be derived through a price spread equation. An excess demand approach to price determination was preferred for monthly or quarterly models as it allowed for short run disequilibrium between supply and demand. Here, the change in price was modelled as a function of change in relative stocks. Since supply is predetermined, and lagged price and beginning stocks are known, current price is a function of closing stocks.

Although Heien provided the theoretical grounds for these processes and gave some empirical examples, there was no indication of the potential differences in complete model solutions under the alternative specifications. This latter issue was addressed by Meilke and Zwart by demonstrating the effects of changing the price determination specification in a world wheat market model on the results of policy analyses based on that model. They noted that although there were few statistical differences in the equation estimates for the price formation alternates, a price dependent specification was preferred for models utilising both quarterly and annual data. More recent work by Chen and Dharmaratne categorised price determination specification options as being either quantity depen-

¹ A further problem was that the earlier model solution algorithms (such as Gauss-Seidel) required a unique equation for each endogenous variable with that variable being dependent.

dent or price dependent, and examined the implications of these specifications on the price simulation performance of a structural wheat market model in relation to an exogenous shock. The importance of this distinction for the price determination process lies in the specification of the price relationship and the simulation method required to solve the model. Quantity dependent models incorporate implicit price determination through the satisfaction of market equilibrium conditions, and are often solved using the Newton procedure. Alternatively, price is explicitly determined in the price dependent models through a renormalised demand function (such as in the price dependent demand model) under the requirements of the Gauss-Seidel algorithm.

3. Options for Price Determination Specifications

The model used for testing the price determination specification options is a quarterly structural model of the Australian lamb market which contains 13 behavioural equations and identities representing the breeding, production, consumption and price formation processes for slaughter lamb (Vere, Griffith and Bootle). Because intended matings for lamb production are assumed to be determined only by the past values of the explanatory variables, the breeding block enters the production block with a lag, while the demand and price blocks are jointly determined by the current values of the endogenous variables. To further test this specification, the residuals of the estimated equations were examined and assessed as being white noise. All data are defined in the appendix along with details of each model's structure and the main summary statistics from the estimation and simulation results. The main model was estimated and simulated over 84 quarterly observations between 1970:1 to 1990:4 using the TSP version 4.2 econometric package.

The main focus of this investigation is on the use of a structural price forecasting model which is varied according to the manner in which farm prices are assumed to be determined². These models attract criticism because of their relatively heavy specification and data demands, and they have a mixed record of success in livestock price forecasting. The studies by Brandt and Bessler and Vere and Griffith (1990) found structural models to be deficient relative to combined quantitative methods, although their forecasts had value in combination with those of other

methods. Alternatively, Leuthold *et al.*, preferred a structural model's price forecasts to the forecasts of an ARIMA model. In a closely related context, Chen and Dharmaratne found that when the farm price determination process was explicitly considered, the structural model offered analytical advantages over the single-equation commodity models because the latter typically assumed that production was price-inelastic in the short run³. Whether the greater input demands of the structural model are offset by improved price forecast information depends on the extent to which the model is capable of explaining past price levels and whether the modelled past behaviour will be repeated over the forecast period (Freebairn 1975). The manner in which prices are formed is expected to be a critical element in determining these capabilities.

To establish whether this is so, the five price determination specification options were incorporated into the basic structure of the model detailed in the appendix. Table 1 contains the estimates of the structural equations required with these specification options.⁴

Traditional specification. This specification follows the Labys approach in which the market model contains structural relationships for breeding decisions, slaughterings, consumption, exports and the farm-retail price spread and a market clearing identity. This model is relevant to most extensive livestock markets as they typically have low levels of stocks. Farm price is determined from a market balance identity equating aggregate supply and demand (equation 1 below) and retail price is formed by the addition of the behaviourally determined price spread to the farm price (equation 1.1 in Table 1).

$$(1) \text{ PDLB} + \text{STLB}(-1) = \text{DMLB} + \text{EXLB} + \text{STLB}$$

² Comparing forecasting methods is not a primary purpose, although some reference is made to the demonstrated benefits of combining forecasts.

³ This assumption was inadequate for farm price analysis because it failed to reflect the dynamic nature of supply response, it ignored the inherent biological lags and inventory adjustments between production decisions and outputs, and it omitted the important effects of other supply and demand components in the market.

⁴ The authors also report the elasticities and flexibilities in Table 1. This additional information is not discussed in the text.

Table 1: Structural Equation Estimates for the Price Determination Options: 1970:1 to 1990:4

Equation - Method dependent variable		Equation Estimates	
1.1 - MMLB	2SLS	53.4 - 0.37 PDLB + 0.58 PALB + 0.08 WAGE (1.71) (-1.44)[-0.44] (1.55)[0.31] (3.32)[0.25] Adj. R ² = 0.28; DW = 1.64; N = 84	
1.2 - PRLB	2SLS- AR1	47.0 - 0.01 YPC - 14.61 DCLB + 0.43 PRBF + 0.24 PRPK + 0.51 PRCH + 8.98 D74 (3.58) (-0.76)[-0.33] (-11.06)[-1.49] (16.09){1.81} (4.51){3.22} (5.52){2.63} (2.51) Adj. R ² = 0.92; DW = 1.99; ρ = 0.04 (0.33); N = 83	
1.3 - PRLB	2SLS	53.4 - 0.37 PDLB + 1.59 PALB + 0.08 WAGE (1.72) (-0.44)[-3.57] (4.22){1.78} (3.12){3.65} Adj. R ² = 0.77; DW = 1.63; N = 84	
1.4 - PALB ^a	2SLS- AR1	85.5 - 0.73 PDLB + 0.57 (STLB-STLB (-1)) + 0.27 PALB(-1) - 0.18 TIME (3.52) (-2.60)[-0.42] (0.99){n.a. ^b } (2.00){0.74} (-3.57) Adj. R ² = 0.52; h = 0.08; ρ = 0.28 (2.7); N = 82	
1.5 - PALB	ARIMA (0,1,2) (0,1,1)	$\Delta Y_t = (1 + 0.56B - 0.37B^2)(1 + 0.95B)^4 \epsilon_t$ (5.37) (-3.62) (39.13) Adj. R ² = 0.62; DW = 1.87; $Q\chi^2$ (2,80) = 22.13; N = 83	
^a quarterly dummy variables omitted. ^b could not be calculated.			

Price dependent demand specification. This specification represents retail price dependency under which retail price is derived behaviourally from a price dependent consumption equation (1.2), and farm price is formed by subtracting the endogenous price spread from the retail price. While Heien proposed price dependency for annual models in which stocks are stable, this argument is also relevant to quarterly livestock models because in this instance, lamb stocks are small and stable and the main source of short-term price variation is in demand, derived from the market balance identity.

Retail price transmission specification. This specification is based on the observation that price simulation problems in econometric models have sometimes been attributed to the price spread equation. Earlier work with this Australian lamb model with the price spread included found that the simulated farm lamb prices were highly variable and negative in some periods, suggesting that the price spread equation was introducing additional variability into the model (this is evident from the relatively poor estimate of equation 1.1). Further analysis confirmed that exogenising the price spread had a major stabilising influence on the farm price solution values (Vere and Griffith 1986). In this price transmission specification, the price spread equation required under the first two

options is replaced by a behavioural price transmission equation (1.3) for retail price which includes the farm price and price spread variables. Farm price is derived from the market balance identity.

Excess demand specification. This specification is based on Heien's notion that short-term differences in supply and demand produce an excess demand which is represented by stocks. While his illustration again concerned a grain market in which stocks were important, excess demand has relevance in this quarterly lamb market model (despite the relative unimportance of stocks) because it better allows for the short-term disequilibria in supply and demand found in most competitive livestock markets. This specification is analogous to the excess demand model for retail price determination in which short-term output is largely predetermined, the regressors are relatively stable and retail price is derived through interaction with the price spread equation. Here, farm lamb prices are expressed as a function of changes in stocks and lagged lamb prices (equation 1.4), and the price spread is endogenous as under the first two options.

Traditional model with exogenous price spread specification. This specification essentially follows the traditional approach with normally specified supply and demand equations and a market balance identity for the solution of farm price. The difference is

that this model incorporates an exogenous price spread (as is specified in the retail price transmission model) and is based on the previously-noted unsatisfactory attempts to behaviourally model this variable, and the more recent findings of Mullen.

An alternate option based on a price dependent-farm quantity specification was not considered to be appropriate in this instance. Price response is incorporated in the model's breeding block and the lamb slaughtering function is essentially a technical relationship between output, past breeding decisions and pastoral and seasonal conditions. Because this function does not incorporate current or lagged farm lamb prices, it cannot be renormalised in price dependent form.

4. Price Forecasting Procedures

Using the general forecasting form of the structural model given in equation (2) below after Intriligator,

the model was used to produce 12 dynamic beyond-sample single-period forecasts of the real farm prices for lamb between 1991:1 to 1993:4 with known exogenous data. This number of forecasts was necessary because the lag structure in the model's breeding inventory and its incorporation in the lamb slaughtering equation requires a minimum eight quarters for price effects to become apparent.

$$(2) \quad \hat{Y}_{T+1} = Y_T \hat{\Pi}_1 + \hat{Z}_{T+1} \hat{\Pi}_2 + \hat{u}_{T+1}$$

where Y_T and Z_{T+1} are respectively row vectors of the predicted values of the lagged endogenous and the exogenous variables, Π_1 and Π_2 are coefficient matrices and u_{T+1} is a row vector of disturbances. Price forecasts were also derived from an ARIMA model (equation 1.5) to test the observation of Granger and Newbold that the strict test of the forecast accuracy of a structural econometric model was whether its forecasts could not be improved through combination

Table 2: Dynamic Simulation Results for the Price Determination Options: 1970:1 to 1990:4

Endogenous variables	Traditional model			Price dependent demand			Retail price transmission			Excess demand			Traditional model with exogenous margin		
	R ²	A/P coef. ^a	Theil U ₂ ^b	R ²	A/P coef. ^a	Theil U ₂ ^b	R ²	A/P coef. ^a	Theil U ₂ ^b	R ²	A/P coef. ^a	Theil U ₂ ^b	R ²	A/P coef. ^a	Theil U ₂ ^b
SWBI	0.98	1.03	0.05	0.97	1.03	0.05	0.98	1.03	0.05	0.97	0.99	0.05	0.98	1.04	0.05
LWBI	0.90	1.02	0.10	0.91	1.03	0.09	0.90	1.03	0.09	0.89	1.03	0.09	0.90	1.02	0.09
CPBI	0.97	0.92	0.08	0.99	0.91	0.08	0.97	0.91	0.08	0.95	0.97	0.08	0.96	0.91	0.08
AUSBI	0.72	0.84	0.02	0.72	0.84	0.03	0.72	0.84	0.03	0.67	0.86	0.03	0.71	0.86	0.02
AUSBX	0.98	1.01	0.04	0.98	1.01	0.04	0.98	1.01	0.04	0.97	1.00	0.04	0.98	1.01	0.03
SLLB	0.68	0.95	0.04	0.68	0.95	0.04	0.68	0.95	0.04	0.67	0.97	0.04	0.69	0.98	0.04
PDLB	0.66	0.99	0.04	0.66	0.99	0.04	0.66	0.99	0.04	0.66	1.02	0.04	0.67	1.02	0.04
DCLB	0.78	1.02	0.04	0.78	1.02	0.04	0.76	1.02	0.04	0.62	0.49	0.09	0.77	1.05	0.04
DMLB	0.62	1.12	0.04	0.62	1.11	0.04	0.62	1.11	0.04	0.41	0.36	0.09	0.63	1.15	0.04
EXLB	0.47	0.80	0.13	0.47	0.80	0.13	0.47	0.80	0.13	0.02	0.05	0.42	0.46	0.76	0.13
PRLB	0.76	0.97	0.03	0.77	0.99	0.03	0.76	0.97	0.08	0.27	0.44	0.07	0.79	1.02	0.03
PALB	0.71	1.00	0.08	0.70	0.99	0.08	0.71	1.00	0.07	0.56	0.94	0.10	0.72	0.86	0.08
MMLB	0.47	0.69	0.04	0.48	0.70	0.04	-	-	-	0.24	0.38	0.07	-	-	-
TREV	0.66	0.77	0.08	0.66	0.76	0.08	0.66	0.77	0.08	0.42	0.98	0.10	0.82	0.83	0.06
^a Coefficient of actual on predicted.															
^b Theil's (1961) inequality coefficient.															

Table 3: Beyond-sample Dynamic Forecasts of Real Farm Lamb Prices Under Alternate Price Determination Specifications: 1991:1 to 1993:4

	Actual data	Traditional model	Price dependent demand	Retail price transmission	Excess demand	Traditional model with exogenous margin
1991:1	19.37	13.83	13.81	13.01	20.97	18.61
1991:2	17.81	13.61	13.66	13.32	22.61	18.74
1991:3	18.34	12.49	12.62	12.37	16.27	15.28
1991:4	12.57	11.24	11.31	11.19	12.33	12.31
1992:1	16.66	7.63	7.75	7.61	17.45	16.04
1992:2	17.02	7.57	7.68	7.56	19.59	16.81
1992:3	18.03	7.07	7.17	7.06	14.36	15.77
1992:4	17.59	4.48	4.64	4.48	7.73	11.97
1993:1	23.67	3.04	3.22	3.04	14.28	13.14
1993:2	22.82	5.24	5.28	5.24	19.01	17.76
1993:3	27.07	5.95	6.13	5.95	10.89	13.41
1993:4	21.04	6.05	6.21	6.05	5.72	10.01
Mean squared error		162.71	155.92	163.93	62.26	41.06
Mean absolute percent error		0.54	0.54	0.55	0.19	0.19

with the forecasts of an ARIMA model⁵. Each set of forecasts were compared according to their mean squared errors and Theil's U₂ statistics.

5. Discussion of Results

The model simulation results reported in Table 2 indicate that all the models, except for the excess demand specification, satisfactorily replicate the process of farm lamb price determination. These models simulate the price series reasonably well (explaining more than 70 per cent of quarterly price variation) and produce similar simulations of the values of the remaining endogenous variables. The traditional model with an exogenous margin specification is the preferred model because it provides the best simulation of the important total lamb industry revenue variable.

Differences in the effects of the price determination options are more apparent in the comparisons of the dynamic farm price forecasts (Table 3)⁶. These confirm the forecasting superiority of the traditional model-exogenous margin specification. In particular, this specification provides the most accurate lamb price forecasts during the wool price slump in 1991. The excess demand model is the only near comparison based on the forecast accuracy criteria, but this model cannot be considered to be a viable alternative because of its poor simulation of the price, demand and revenue variables relative to the preferred model.

Combining the individual structural model's forecasts with those of an ARIMA model (on a 50:50 basis) improved the forecast accuracy of all specifications (Table 4). This result is consistent with other studies which have favoured the use of composite econometric methods for livestock price forecasting (such as the Bessler and Brandt studies and Vere and Griffith 1990). It indicates that the component models contributed independent information which improved the forecasts of farm lamb prices (Bates and Granger).

⁵ The estimated ARIMA price forecasting model is;
 $PALB \Delta Y_t = (1 + 0.561B - 0.377B^2)(1 + 0.949B)^4 = \epsilon_t$
 ARIMA (0,1,2) (5.36) (-3.62) (39.12)
 (0,1,1)

Adj. R² = 0.62; DW = 1.858; Q χ^2 (3,22) = 22.13;
 lag length = 25.

Residual autocorrelations for 5-period lags:
 $\hat{\alpha}_1 = 0.05$; $\hat{\alpha}_5 = -0.01$; $\hat{\alpha}_{10} = 0.12$; $\hat{\alpha}_{15} = -0.14$; $\hat{\alpha}_{20} = 0.05$;
 $\hat{\alpha}_{25} = 0.07$.

⁶ The relatively poor 1993 forecasts are considered to be due to the lack of published data available to update the model's data base beyond 1993:4. This is because the model utilises a lag structure on prices which in part, requires a minimum eight quarters to operate as intended. This, coupled with the necessity to include the effects of the 1991 wool market deregulation in the forecast evaluation period, meant that there were only 12 quarters available beyond the estimation sample to produce and compare the forecasts.

Table 4: Beyond-sample Dynamic Forecasts of Real Farm Lamb Prices Combined with ARIMA Forecasts: 1991:1 to 1993:4^a

	Actual data	ARIMA model	Traditional model	Price dependent demand	Retail price transmission	Excess demand	Traditional model with exogenous margin
1991:1	19.37	18.66	16.25	16.23	15.83	19.82	18.64
1991:2	17.81	20.35	16.98	17.01	16.64	21.48	19.55
1991:3	18.34	17.94	15.22	15.28	15.16	17.11	16.61
1991:4	12.57	13.23	12.24	12.27	12.21	12.78	12.77
1992:1	16.66	16.57	12.11	12.16	12.09	17.01	16.31
1992:2	17.02	19.36	13.47	13.52	13.46	19.48	18.09
1992:3	18.03	16.95	12.01	12.06	12.01	15.66	16.36
1992:4	17.59	12.24	8.36	8.44	8.36	9.99	12.11
1993:1	23.67	15.58	9.31	9.41	9.31	14.93	14.36
1993:2	22.82	18.37	11.81	11.82	11.81	18.69	18.07
1993:3	27.07	15.96	10.96	11.05	10.96	13.43	14.69
1993:4	21.04	11.25	8.65	8.73	8.65	8.49	10.63
Mean squared error			76.33	75.39	76.63	43.52	34.32
Theil's statistic ^b			6.39	6.32	6.42	3.65	2.87

^a Weighted on a 50/50 basis with each of the structural model's forecasts.
^b Ratio of mean squared errors of forecasting model and no-change model.

Again, the traditional model with an exogenous margin is clearly superior in terms of the forecast accuracy criteria.⁷

The main result therefore is that the nature of the assumed price formation process in a structural livestock market model can have a major influence on the model's solution and on its ability to forecast farm prices. Considering this Australian lamb market model, the main option for improving farm price forecasts utilises a model which incorporates quantity-dependent supply and demand equations and solves farm price through a market balance identity. This model is similar to the Labys approach in which there is no specific or renormalised price equation, but it differs with the relative importance of stocks and in the exogenous determination of the farm-retail price spread. Accordingly, this specification appears to be most applicable to a livestock market in which stocks and exports are relatively small and domestic demand is relatively stable, and it is therefore preferred on this basis. This implication that supply variations are the main source of farm price changes is consistent with the observed cyclical nature of livestock supply response resulting from the biological lags and constraints on production (Rucker *et al.*).

The price dependent demand option follows Heien's notion of retail price dependency in which stocks have little market importance. It differs from the traditional options with the assumptions of short-run supply fixity and that retail price changes are caused by demand variations which transfer through the price spread to similarly influence farm prices. This behaviour does not appear to apply to the Australian lamb market. The excess demand model produced conflicting results which might be attributed to the negligible role of stocks in this market compared to their importance in Heien's example.

6. Conclusion

This study has investigated the effects of alternate farm price determination processes in a structural livestock market model and their implications for the model's ability to forecast farm prices. It has been based on the proven superiority of econometric fore-

⁷ One referee points out that the overall forecast accuracy for the chosen specification has been lowered by the poor prediction for 1993, and leaves room for later improvement.

casting methods and composites of such to other approaches, and the expectation that the use of a properly specified and validated model incorporating the supply and demand sides of the market and their interactions in determining prices, would offer accuracy advantages in forecasting the farm-level prices for livestock products.

The main conclusion is that the manner in which the price determination process is specified can have a significant effect on the model's simulation and its value as a price forecasting mechanism. In this specific application to the Australian lamb industry, the result demonstrate that the traditional market balance specification of price determination when incorporated with an exogenous price spread, improves both the simulation performance and the price forecasting performance of a structural model of the industry. In models of other industries, choice of the most appropriate price determination specification will need to be based on knowledge of industry behaviour, particularly in relation to the importance of stocks. Different price determination specifications may prove to preferable in markets which more closely approximate those for which they were proposed.

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APPENDIX

Data Definitions and Sources

Endogenous variables

AUSBI:	seasonally adjusted breeding inventory, (m), calculated,
AUSBX:	total adjusted breeding inventory, (m), calculated,
CPBI:	intended matings to other meat rams, (m), ABS,
LWBI:	intended matings to long wool rams, (m), ABS,
SWBI:	intended matings to short wool rams, (m), ABS,
DCLB:	per capita lamb consumption, (kg/head), calculated,
DMLB:	consumption of lamb, (kt), AMLC,
EXLB:	lamb exports, (kt), AMLC,
PALB:	farm lamb price, (c/kg), AMLC,
PDLB:	lamb production, (kt), AMLC,
PRLB:	retail price of lamb, (c/kg), ABARE,
SLLB:	lambs slaughtered, (m), AMLC,
TREV:	total lamb industry revenue, (\$'000), calculated.

Exogenous variables

AFAU:	improved pasture area fertilised, (m ha), ABS,
CPIA:	Australian consumer price index, ABS,
DDRT:	dummy variable, drought = 1,
D74:	dummy variable, 1974:4=1, export beef market shock,
PFWH:	average export wheat price, (\$/t), ABARE,
PFWL:	average wool price, (c/kg clean), IWS,
PIAU:	improved pasture area, (m ha), ABS,
POPA:	Australian population, (m), ABS,
PRBF:	retail beef price, (c/kg), ABARE,
PRCH:	retail chicken price, (c/kg), ABARE,
PRPK:	retail pork price, (c/kg), ABARE,
MMLB:	price spread for lamb, (c/kg), calculated,
PW27:	average 27 micron wool price, (c/kg clean), IWS,
STLB:	closing stocks of lamb, (kt), AMLC,
TIME:	trend, 1 in 1965 (3), 2 in 1965 (4), etc.,
WAGE:	wages, meat processing sector, (\$/week), ABS,
YPCA:	household disposable income, (\$m), ABS.

^a ABARE is the Australian Bureau of Agricultural and Resource Economics, ABS is the Australian Bureau of Statistics, AMLC is the Australian Meat and Livestock Corporation, IWS is the International Wool Secretariat.

Structure, Estimation and Simulation of the Australian Lamb Model: 1970:1 to 1990:4									
Endogenous variable	Main explanatory variables			Method	Estimation statistics		Dynamic simulation statistics		
					R ²	DW(h)	R ²	A/P ^a	Theil U ₂
SWBI	f ^d	lagged prices, season, lagged dependent variable		OLS ^b	0.99	(-0.46)	0.98	1.03	0.05
LWBI	f	lagged prices, pasture area, lagged dependent variable		OLS ^b	0.98	(-1.19)	0.90	1.03	0.09
CPBI	f	lagged prices, season, lagged dependent variable		OLS	0.99	(-0.21)	0.96	0.92	0.08
AUSBX	=	disaggregated breeding inventory					0.77	0.94	0.03
AUSBI	=	AUSBX with annual and seasonal lags					0.98	1.01	0.02
SLLB ^c	f	lagged adjusted inventory, lagged wool prices, lagged dependent variable		OLS	0.79	(-0.46)	0.71	0.99	0.04
PDLB	=	slaughterings, average carcase weight					0.71	1.03	0.04
DMLB	=	per capita consumption, population					0.66	1.13	0.04
DCLB ^c	f	own and other retail meat prices, income		2SLS	0.94	1.97	0.79	1.05	0.04
EXLB ^c	f	production, lagged export price, opening stocks		2SLS ^b	0.61	1.95	0.48	0.77	0.13
PRLB	=	farm prices, marketing margin					0.78	0.97	0.03
PALB	=	market clearing identity					0.73	0.85	0.08
TREV	=	farm prices, production					0.83	0.85	0.06
^a Coefficient of actual on predicted. ^b Corrected for first-order autocorrelation. ^c Quarterly and impact dummy variables omitted. ^d f denotes a behavioural equation: = denotes an identity.									

Price Determination Options for the Australian Lamb Model									
Endogenous variable	Traditional model	Price dependent demand		Retail price transmission		Excess demand		Traditional model with exogenous margin	
	fn ^a	RHS endogenous variable	fn	RHS endogenous variable	fn	RHS endogenous variable	fn	RHS endogenous variable	fn
SWBI	f	SWBI _t , PALB _L	f	n c ^b	f	n c	f	n c	f
LWBI	f	LWBI _t , PALB _L	f	n c	f	n c	f	n c	f
CPBI	f	CPBI _t , PALB _L	f	n c	f	n c	f	n c	f
AUSBI	=	SWBI, LWBI, CPBI _L	=	n c	=	n c	=	n c	=
AUSBX	=	SWBI _t , LWBI _t , CPBI _L	=	n c	=	n c	=	n c	=
PDLB	=	SLLB	=	n c	=	n c	=	DMLB, EXLB	=
SLLB	f	SLLB _t , AUSBI _L	f	n c	f	n c	f	n c	f
DMLB	=	DCLB	=	PDLB, EXLB	=	n c	=	n c	=
DCLB	f	PRLB	=	DMLB	f	n c	f	n c	f
EXLB	f	PDLB, PALB _L	f	n c	f	n c	f	n c	f
PALB	=	PDLB, DMLB, EXLB	=	PRLB, MMLB	=	n c	f	PALB _L	=
PRLB	=	PALB, MMLB	f	DCLB	f	PDLB, PALB, PALB _L	=	n c	=
MMLB	f	PDLB, PALB, PALB _L	f	n c	-	n c	f	n c	-
TREV	=	PDLB, PALB	=	n c	=	n c	=	n c	=

^a f denotes a behavioural equation; = denotes an identity.

^b n c denotes that the equation is unchanged from the traditional model.