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Beef Cow Inventory Response: An Attempt to Apply the Adaptive Risk Model*

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An analysis of variations in the annual inventory of beef cows and heifers at the regional level in New South Wales using Just's adaptive risk model is reported. The State has been divided into six relatively homogeneous regions for the purposes of the study. Wherever significant coefficient estimates are obtained, inventories in the various regions are positively related to expected beef price and the variance of prices of alternative commodities and negatively related to expected prices of alternative commodities and the variance of beef price. Some of the limitations of the adaptive risk model in analysing the beef industry are discussed.

Introduction

Beef cattle producers make production decisions under uncertainty. Imperfect knowledge of prices and climatic conditions, especially, introduce risk into the decision making environment of farmers. The climatic uncertainty as it affects beef cattle production and the relative profitability of alternative enterprises is likely to be different between regions in New South Wales. Beef production is not a dominant agricultural industry in any region. The industry must compete for available production resources with other industries such as grain, sheep, and dairy production. The mix of farm enterprises tends to differ between regions, depending on soils, topography, rainfall, temperature, and length of growing season. However, while the physical environment is important, changes in the economic environment due to changes in market conditions, technology, technical competence of farmers, and attitudes of farmers to risk are likely to affect the relative profitability of alternative farm enterprises. Changes in the structure of rural industries in each region may then be observed.

This study is concerned with inventory response in the cow and heifer portions of the beef herds in the regions of New South Wales. Cow and heifer inventory is of interest because of its dual role as either direct slaughter animals or producers (i.e., breeders) of future slaughter animals. Farmers' decisions on whether to commit female cattle for slaughter or to keep them in the breeding herd affects the level of production in the longer term. Past studies have

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identified the significance of the inventory of female beef cattle on production (e.g., Freebairn 1973; Longmire and Main 1978; Reeves *et al.* 1980; Reutlinger 1966). Knowledge of changes in the female portion of the beef herd is important in understanding the structure of the industry and in forecasting (e.g., Weeks and Reynolds 1981).

Imperfect knowledge of future profits necessitates farmer decision making on the basis of 'expected' output prices, yields and input costs. Farmers may modify production decisions in response to changes in the level of uncertainty about expected profits. In other words, output may respond to changes in risk; an aspect of the farmers' decision making environment which is often ignored in econometric studies in the livestock sector. Studies which have identified the responsiveness of livestock industry outputs to risk include the work of Freebairn (1973) and Freebairn and Rausser (1975). A number of studies have been concerned with response to risk in annual crop industries (e.g., Behrman 1966, 1968; Brennan 1981; Just 1974*a*, 1974*b*, 1976; Ryan 1977; Traill 1978; Wilson *et al.* 1980); but these industries are not characterized by dynamically complex production processes, such as found in the livestock sector.

It is plausible that the effect of risk on the inventory of female beef cattle will differ among regions. There are at least two reasons why differences should be observable; both largely due to variation in the physical environment. Firstly, the class of competing decision variables faced by farmers is not homogeneous across all regions; and secondly, the correlations among the variables are likely to differ. Therefore, a change in a decision variable may have a more significant influence on inventory in some regions than in others depending on the unique sets of constraints in each region. For example, a change in the variance of beef prices, *ceteris paribus,* is likely to lead to a reallocation of resources among competing enterprises in order to maximize some objective function. The direction and extent of the flow of the resources are restricted by the constraints in each region. It is assumed that resources will move from more risky enterprises to less risky enterprises in order to maximize utility.

A number of studies have been concerned with the nature of the underlying structural factors which are expected to influence beef cattle inventory. A selection of these studies have been discussed by, for example, Askari and Cummings (1976), Bain (1977), and Reeves *et al.* (1980). Typically, inventories are modelled as a system of identities within a multi-equation modelling framework. The behavioural decisions are slaughterings and natural increases and these correspond with decisions about inventory. Sometimes, however, stochastic equations explaining inventories are estimated. Generally, the equations specified to explain variations in the annual inventory of breeding cows have, as dependent variables, the dependent variable lagged one year, expected prices of beef and alternative commodities[1], and other shift variables peculiar to the local industry such as weather conditions, level of technology, and feed grain supplies. Variance of beef prices was included by Freebairn (1973), Freebairn and Rausser (1975), and Reeves (1980).

The aim of this study is to analyse regional inventory response in the female beef cattle sector of New South Wales with particular emphasis on the

1. Expected prices are typically defined by actual prices in the current or some past period; or as a function of these prices.

significance of risk variables. Freebairn found evidence that beef cattle producers in New South Wales "... as an aggregate are risk averters" (p. 66). A relatively simple definition of risk—the range of prices between the current year and up to two years in the past—was used; but Freebairn noted that a "... more appropriate measure would be a moving variance estimate" (footnote, p. 58). In the next section, a more general empirical model is developed to partially describe the structure of inventory response. The model is based on Just's (1974*b*) adaptive risk model and the important decision variables in a beef cattle breeding enterprise. A brief outline of the method of estimation for the study is also provided. The rationale for the regional boundaries chosen and the competing commodities included is presented in the third section. This is followed by a report of the results of the empirical estimation of the regional models. The conclusions and implications arising from the study are contained in the final section.

Model

Theories of production and utility relate to the behaviour of the individual firm. Thus, the individual firm (i.e., the 'typical' farm within a region) is assumed to represent the region in aggregate. Although this approach is likely to lead to aggregation bias, it is considered to be appropriate in the absence of a parallel theory of the region or industry. The concept of quadratic utility response and the physical constraints associated with agricultural production are used to specify an econometric model for empirical analysis of annual inventory of cows and heifers.

It is assumed that the decision maker desires to maximize utility which is expressed in terms of the mean and variance of the profit stream from on-farm investment. This objective function is subject to constraints imposed by the farm's production function. The constraints considered to be important in this study are calving rate, breeding cow slaughter rate, female calf slaughter rate, heifer slaughter rate, breeding cow replacement rate, heifer growth rate, land availability, pasture resources and rainfall. Clearly, these variables are not mutually exclusive. The relationships assumed to underlie the study are adapted from constraint functions used by Freebairn (1973, p. 84).

A system of identities provides the basis for the specification of economic relations which are hypothesized to explain variations in the numbers of female beef cattle. The identities equate the gains and losses to the total number of female beef cattle in year t through purchases, sales, slaughterings, mortalities, births and net agistments. That is, for any given region in New South Wales,

$$(1)\ IFC_t = IFC_{t-1} + SSFC_t + NAFC_t + CF_t$$

$$(2)\ SSFC_t = YFC_t - XFC_t - SFC_t - MFC_t$$

$$(3)\ NAFC_t = QFC_t - RFC_t$$

$$(4)\ CF_t = \Omega\delta\psi(IB_{t-1} + YB_t + QB_t)$$

where

IFC = closing number of all female beef cattle;

$SSFC$ = annual number of purchases less sales, slaughterings and mortalities of all female beef cattle;

$NAFC$ = net closing number of female beef cattle agisted in the region;

CF = number of female beef calves born;

YFC = annual purchases of all female beef cattle;

XFC = annual sales of all female beef cattle;

SFC = annual slaughterings of all female beef cattle;

MFC = annual mortalities of all female beef cattle;

QFC = closing number of all female beef cattle agisted in the region plus the number returned to the region after being agisted out the previous year;

RFC = closing number of all female beef cattle agisted out of the region plus the number moved out of the region after being agisted in the previous year;

IB = closing number of beef breeding cows and heifers;

YB = annual purchases of beef breeding cows and heifers;

QB = closing number of beef breeding cows and heifers agisted in the region plus the number returned to the region after being agisted out the previous year;

Ω = proportion of calves born as females;

δ = birth rate of breeding cows and heifers;

ψ = proportion of breeders reaching parturition before sale, agistment out of the region, slaughtering or death;

t = time period of length one year (denotes inventories at end of year t; for all other variables, the subscript denotes averages or totals during year t).

Equation (4) relates the numbers of calves born in year t to the numbers of breeding cows and heifers available from the opening inventory, purchases and 'agisted in' categories which are present in the region for at least nine months (i.e., the gestation period) after mating.

The pasture resources which are available for utilization by livestock are assumed to be related to seasonal conditions and area of improved pastures. Thus

(5) $PR_t = g\,(SI_t, IP_t)$

where

PR = pasture resources;

SI = seasonal conditions in terms of percentage variatior from annual average rainfall;

IP = area of improved pastures.

Ideally, one would like to disaggregate IFC, $SSFC$ and $NAFC$ into breeding cow, fattener (or cull) female, unjoined heifer and female calf components. However, statistics are not available. Therefore, the approach adopted is to restrict the analysis to inventories of cows and heifers aged one year and over and assume that

(6) $ICH_t = IFC_{t-1} + SSCH_t + NACH_t$

(7) $SSCH_t = f_2\,(IFC_{t-1}, PB_t, VB_t, PA_t, VA_t, SI_t, IP_t)$

(8) $NACH_t = f_3\,(PB_t, VB_t, PA_t, VA_t, SI_t, IP_t)$

where

ICH = closing inventory of cows and heifers aged one year and over at 31st March;

$SSCH$ = annual net change in cow and heifer numbers through purchases, sales, slaughterings and mortalities, including heifers which were calves at the beginning of the year;

$NACH$ = annual net numbers of cows and heifers on agistment;

PB = expected price of beef;

VB = price variance (risk) of beef;

PA = expected weighted price of alternative farm commodities;

VA = price variance (risk) of alternative farm commodities;

and IFC, SI, PI and t are as earlier defined.

The recursive model implies that in a given region the closing inventory of cows and heifers in year t is equal to the sum of the previous year's closing inventory of all female cattle and net change in numbers due to purchases, sales, slaughterings and mortalities, and agistment.

Intuitively, the factors causing variation in purchases, sales, slaughterings, and mortalities of cows and heifers are the same as those determining closing inventory. Firstly, there are expectations about future profits to be accrued through the maintenance or build-up of current inventory compared to the returns from the liquidation (through slaughterings and sales) of current inventory. Secondly, there are risks associated with actually realizing expected profits which in turn affects farmers' actions in maintaining, building-up or liquidating inventories. Thirdly, there are expectations and risks associated with profits from alternative enterprises which compete with female beef cattle for available resources. Fourthly, pasture availability affects inventory in that it may influence turn-off rate, stocking rate, and mortality rate.

It was earlier assumed that farmers wish to maximize utility as represented by the mean and variance of some stream of profits from available alternative enterprises. Profits, in turn, are composed of the income and costs associated with the production of output from the adopted enterprises. Variations in profit will arise from non-counteracting variations in output, output prices, inputs and input prices. Due to lack of data on regional output of beef and input use it is necessary to represent profit by observations on prices. The implications of this assumption relate to the exclusion of variations in output and input costs to explain variations in inventory. However, these variations are likely to be accounted for by the variables associated with pasture production and alternative commodities, respectively. That is, production is affected by pasture availability. The mean and variance of prices of alternative commodities are surrogates for the distribution of the opportunity costs of beef breeding (e.g., Tomek and Robinson 1972, p. 62); for example, an increase in input costs for beef production may effect a shift in resources to alternative enterprises which exhibit a higher marginal value product.

Thus, the net change in inventory through slaughterings, sales, mortalities and purchases is assumed to be influenced by closing inventory of cows, heifers and female calves in year $t-1$, expected prices and price variances of beef and alternative commodities in year t, seasonal conditions in year t, and the area of improved pastures in year t. The expected beef price distribution in year t is given by the expected mean and variance variables and represents the uncertainty about future prices of beef resulting in part from current decisions. The variables associated with alternative enterprises to beef breeding are PA and VA.

The net number of agisted cows and heifers in year t is assumed to be related to price expectations and risks which in turn are assumed to be measures of the value of these animals as capital goods. Decisions about the level of net agistment are, of course, influenced by availability of pastures; hence the inclusion of the variables (SI and IP) to account for pasture resources.

Substituting the expressions for net change in inventory of cows and heifers in year t into the closing inventory function yields the following:

(9) $ICH_t = f_4\ (IFC_{t-1}, PB_t, VB_t, PA_t, VA_t, SI_t, IP_t)$

which can be empirically analysed using available data[2]. Thus it is hypothesized that closing inventory of beef cows and heifers (aged one year and over) in a given region in year t is a function of opening inventory of total female beef cattle in the region, expected means and variances of prices of beef and alternative commodities in the region, seasonal conditions, and area of improved pastures.

Adaptive Expectations and Risk

Since the pioneering works of Koyck (1954), Cagan (1956) and Nerlove (1958), several authors have applied models based on the assumption of a declining geometric lag in empirical supply response studies (e.g., Askari and Cummings 1976, 1977). This form of lag has been favoured for a number of reasons. It is intuitively appealing and simple estimation methods such as ordinary least squares and generalized least squares can often be used. Good statistical fit is usually obtained if the model specification is 'correct' given the restrictions imposed. There is a saving in degrees of freedom for the estimation process (e.g., Johnston 1972, p. 293). The assumption of geometric weights leads to the correction of persistent errors in forecasting without responding very much to random disturbances (e.g., Muth 1961, p. 299)[3]. However, these studies usually assume a situation of constant risk so that only the means of observed information variables (such as prices) are included as explanatory variables.

Just (1974*a*, 1974*b*, 1976, 1977) opts for a "... more generally applicable class of models ... based on a changing subjective knowledge of the economic environment in which the decision maker operates" (1974*b*, p. 2). Just (1974*b*) shows that temporal variation in parameters of the observed state of the environment upon which entrepreneurs make decisions (such as prices paid, prices received, and productivity of various production processes) can be adequately explained by the geometric lag distribution. Geometric weightings are attached to the means and variances of observed information variables in a situation of changing risk; thereby including variables to explain the decision maker's personal or subjective probability density function of the state of the economic environment in an econometric model.

Just's *adaptive risk model* forms the basis for the specification of expected prices and risk variables in this study. Expected price of beef and expected weighted price of alternative commodities in year t are each given by the general term,

$$(10)\quad X_t^* = \theta \sum_{k=0}^{\infty} (1-\theta)^k X_{t-j-k-1},\ 0 < \theta \leq 1$$

2. Empirical analysis of functions (7) and (8) is not possible because statistics on regional purchases, sales, slaughterings, mortalities, and agistments are not available.

3. In a more pragmatic approach, Fisher and Tanner (1978) found empirical evidence in the Australian rural sector for the use of geometric lags.

where X^*_t is the decision makers' subjective expectations for the mean of prices of some commodity in year t; X_{t-j} is the observed price of the same commodity in year $t-j$. The price in year $t-j$ is the past price which has the greatest influence in the formation of expected prices in year t. For convenience, θ is assumed to have the same value in the expressions for the expected prices of beef and alternative commodities. This means that the same weight is imposed on prices from the same year in the past. Risks in beef prices and the prices of alternative commodities in year t are given by the general term,

$$(11) \quad W^*_t = \varnothing \sum_{k=0}^{\infty} (1-\varnothing)^k W_{t-j-k-1}, \; 0 < \varnothing \leq 1$$

where W^*_t is the decision makers' subjective expectations for the variance of prices of some commodity in year t; and W_{t-j} is the variance of the observed prices of the same commodity in year $t-j$. W_{t-j} is given by $(X_{t-j} - X^*_t)^2$ and defines *risk* in terms of the most recent observations on actual and expected prices. In this case, W_{t-j} is a variable representing *uncertainty* which occurs as a result of the unknown difference between actual and expected outcomes in a given period. $\varnothing$, like θ, is the same for both risk variables.

In equations (10) and (11), expected prices and risk variables are specified with a 'lag' of j years. The length of delay before the beginning of the geometric lag structure is expected to be determined by both the biological nature of beef cattle breeding and the system of production[4]. In regions where it is common practice to breed replacement heifers and older slaughter cattle (that is, over two years old), the lag is expected to be three years. This is the approximate period of time that it takes to achieve an outcome following a decision to increase the sizes of the breeding herd or slaughter turnoff[5]. The lag would be shorter during periods of herd liquidation. However, such responses have only occurred twice during the period of observation: in the mid 1960's due to drought and the late 1970's due to a decline in beef prices. A lag of $j=1$ or 2 is expected in regions oriented towards the breeding and turnoff of younger cattle (i.e., vealers and yearlings).

Estimation Method

The chosen method of estimation for the study is based on Just (1976). The method allows the direct estimation of the non-linear model resulting from the assumption of geometrically declining lag schemes for expected price and risk. The method requires the division of the expected price and risk variables into observable and unobservable parts similar to the approach taken by Klein (1958). That is, if we have $T+1$ observations indexed by $t=0, 1, 2, \ldots, T$, then equation (10) may be rewritten as,

4. The likely importance of the system of production as a factor affecting the value of j was highlighted by one of the referees.

5. Young (1968*a*) found that bulls are paddocked with cows for approximately three months in commercial beef herds in New South Wales. Add to this the length of the gestation period for cattle which is nine months. Further, Young (1968*b*) reported that the most common joining age of heifers in the State is 24 to 27 months. This gives a total of approximately three years.

(12) $$X_t^* = \theta \sum_{k=0}^{t-j-1} (1-\theta)^k X_{t-j-k-1} + (1-\theta)^{t-j} X_j^*$$

where $t = j+1, j+2, \ldots, T$, and X_j^* is a parameter which shall be set to some fixed value. The same disaggregation process is also applied to the risk variable, W_t^* in equation (11) (e.g., Just 1976, p. 676). Maximum Likelihood (ML) estimates of the coefficients of the model, under the assumption of normally and independently distributed disturbances, may then be formed; the ML estimates being obtained via non-linear least squares using the Gauss-Newton algorithm (e.g., Judge *et al.* 1980, pp. 735–6).

Data

New South Wales is divided into six regions for the purposes of this study. The regions are: Coast, Northern Tablelands, Central and Southern Tablelands, Northern Slopes and Plains, Central and Southern Slopes, and Western Plains. Each region is regarded as being relatively homogeneous in terms of land use and length of growing season. The boundaries are adapted from the regional classifications used by the Bureau of Agricultural Economics (e.g., Longmire *et al.* 1979, pp. 30–5; Davidson 1967) and the Statistical Agricultural Areas of New South Wales used by the Australian Bureau of Statistics (e.g., A.B.S. 1979).

The inventory of female beef cattle in the study is defined as the number of cows and heifers mainly for beef production aged one year and over and half the number of beef calves aged less than one year at 31 March in each year. The time period used is from 1950 to 1978 inclusive.

Wool and wheat production are assumed to be the major competing enterprises affecting female beef cattle inventory in all regions with the exception of the Coast region. Revenue from wool production in the Northern Tablelands and Central and Southern Tablelands regions ranges between 60 per cent and 100 per cent of total revenue from wool and wheat in the period 1950 to 1978. In the Central and Southern Slopes and Northern Slopes and Plains regions, revenue from wheat production is greater than wool revenue in all years except 1958. There has tended to be a shift over time in the relativity between wool and wheat revenues in the Western Plains region; prior to the mid 1960s, wool contributed the greater proportion[6].

Although dairy production is a major industry in the Coast region, changes in expected price and risk of dairy products did not significantly influence beef cow and heifer numbers in preliminary estimation. The probable reason for these results is that most beef cattle breeding enterprises in the region are confined to the poorer hilly areas which are unsuitable for dairying. Another major industry in the region is sugar production. However, sugar and beef cattle do not actively compete for the same land resources. Beef breeding enterprises in the Coast region are assumed to have no major competitors in the following empirical analysis.

6. Unfortunately statistics on beef output in the various regions are not available, thus preventing comparisons between revenues from beef production and alternative enterprises.

The same beef, wool and wheat prices are used for each region. Average prices for the year ending 30th June, 1950 to 1978, for export quality ox at Homebush, and greasy wool at auction and wheat at the farm gate in New South Wales are used. All prices are deflated by the index of Prices Paid by Farmers for the State. Observations on the weighted price of alternative commodities are obtained by constructing a Paasche price index series (e.g., Tomek and Robinson 1972, p. 206) using annual prices and quantities of the major alternative commodities in each region. Percentage variation from the 'normal' annual average rainfall in each region is used as a surrogate for seasonal conditions. Improved pastures are measured in terms of the areas of sown grasses and clovers in each region at 31st March in each year. The data series are available from the author.

Results

The preferred results of empirical estimation of the model for each region are presented in Table 1. Preliminary estimation indicated that the theoretical model given by equations (9) to (11) was not consistent with the available data in all regions. The results reported were obtained by firstly experimenting with different lengths of delay before imposing the geometric lag structure on the formation of expected prices and risk. The criteria used in comparing alternative lengths of delay were the signs on the estimated coefficients in terms of prior expectations, and measures of 'goodness of fit' (R^2) and autocorrelation (Durbin-Watson statistic)[7]. Explanatory variables with insignificant estimated coefficients were then omitted where their exclusion did not unduly affect the interpretation of the other estimates. The ratios of coefficient estimates to their asymptotic standard errors are given in parentheses.

The estimated coefficients in Table 1 have the expected signs. In each region, both the opening inventory of all female beef cattle and the expected price of beef are positively related to closing numbers of cows and heifers. Negative coefficients were obtained on the beef risk variables in the equations for the coastal and northern regions. The expected weighted prices of alternative commodities have a negative effect on cow and heifer numbers in the Slopes and Plains regions; whilst the corresponding risks variables have a positive effect in these regions.

The improved pastures variable was omitted from the reported equation for the Coast region. The most likely reason that this variable is superfluous is that the physical factor most limiting upon beef production in the region is soil fertility. The adoption of technologies to increase soil fertility and improve pastures has not been extensive. Estimated coefficients on seasonal conditions are not significant in the Coast and Northern Tablelands regions. A suggested reason for these results is that stocking rates are relatively low in these regions, enabling breeding cattle to more readily withstand drought conditions.

Response to own-price variance is not significant in central, southern and western regions of the State; whilst response to cross-price variance is not

7. The relevance of R^2 and the D.W. statistic for testing hypotheses about the estimates is questionable. However, in the absence of more conclusive tests, these measures are used to indicate possible serious statistical errors (e.g., Judge *et al* 1980, p 255; Kenkel 1974).

Table 1: Non-linear Least Squares Estimates of Annual Cow and Heifer Inventories in the Regions of New South Wales: 1950 to 1978

Explanatory Variables[b]	Regions					
	Coast	Northern Tablelands	Northern Slopes and Plains	Central and Southern Tablelands	Central and Southern Slopes	Western Plains
Constant	−91	−215	−341	−588	−295	−66
IFC_{t-1}	0.78 (34.71)	0.32 (1.82)	0.19 (0.82)	0.35 (3.07)	0.39 (5.84)	0.58 (11.59)
PB_t	2.96 (3.31)	7.38 (1.81)	20.73 (1.62)	15.45 (1.83)	17.42 (2.72)	2.47 (4.25)
VB_t	−0.06 (−2.06)	−1.30 (−2.12)	−2.21 (−1.52)			
PA_t			−470 (−1.32)		−806 (−1.42)	−37.06 (−1.34)
VA_t			947 (0.93)		3922 (0.75)	53.31 (1.02)
SI_t			0.81 (1.42)	0.78 (3.72)	1.16 (6.21)	0.25 (4.34)
IP_t		0.17 (2.79)	0.62 (2.24)	0.15 (3.25)	0.08 (1.96)	0.38 (2.08)
θ	0.61 (2.01)	0.39 (3.80)	0.42 (4.26)	0.15 (2.00)	0.17 (3.26)	0.63 (5.02)
ϕ	1[c]	0.39 (2.45)	0.48 (1.75)		0.13 (0.96)	1[c]
j[d]	1	3	3	2	1	2
R^2	0.99	0.99	0.98	0.99	0.99	0.99
D.W.	1.72	2.18	1.57	1.72	1.69	1.90

(*a*) Figures in parentheses are ratios of coefficient estimates to their standard errors.

(*b*) Descriptions of the variables are provided in the text.

(*c*) Restricted Maximum Likelihood estimates were obtained at the boundary point $\phi = 1$ i.e. $W^*_t = W_{t-j-1}$.

(*d*) j is the delay in lag, i.e. period $t-j$ is the beginning of the geometric declining lag scheme on past price means and variances.

significant in the Tablelands (and Coast) regions[8]. A possible reason for these results is that the level of aggregation of the regions is too high. Thus, certain enterprises may not be sufficiently important to obtain significant responses to changes in their price risk in estimating the model used in this study (e.g., Just 1974*a*).

The values of j reported in the Table conform to expectations. The Coast and Central and Southern Slopes are considered to be regions where the major turnoff is young cattle; that is, weaners and vealers. For these regions, $j=1$. The northern regions, namely the Northern Tablelands and the Northern Slopes and Plains, tend to turnoff older cattle. In the estimated equations for these latter regions, $j=3$.

Conclusion

This paper is concerned with an analysis of beef cow and heifer inventory response in the regions of New South Wales. Separate equations are estimated for each of six relatively homogeneous agricultural regions in the State. The estimated equations are based on a general equation in which cow and heifer numbers are expressed as a function of the lagged total number of female beef cattle, expected prices and price risks of beef and alternative commodities, seasonal conditions and area of improved pastures. The expected price and risk variables are specified by imposing geometrically declining weights on past observations on the respective variables.

The reported results indicate that the empirical estimation of the general equation to explain variations in cow and heifer inventory does not provide statistically significant values of all coefficients in the individual regional equations. For example, and of particular interest, are the relationships between regional inventory and the risk variables.

Risk (or variance) in beef prices is significantly and negatively related to annual inventories of cows and heifers in the Northern Tablelands, Northern Slopes and Plains, and Coast regions. A suggested reason for the results is that beef production in these regions is oriented towards breeding activities. These regions produce cattle which may be fattened locally, but are often turned off in store condition for fattening in other regions, commonly in central and southern New South Wales, and Victoria. Since the demand for store cattle is mainly derived in other regions and is likely to be responsive to changes in beef prices, risks are imposed upon beef breeding enterprises in the northern and coastal regions.

In the Slopes and Plains regions of the State, risks in prices of alternative commodities influence annual numbers of cows and heifers. The results indicate that changes in farmers' subjective expectations on the variances of wool and wheat prices have a significant impact on breeding cattle numbers in the so-

8. The ratio of the coefficient estimate for cross-price variance to its asymptotic standard error in the Northern Slopes and Plains region is low. Attempts to omit this variable led to results which were less preferable. Some alternative specifications of the variable might provide more conclusive estimates. However, it is beyond the scope of this study to test them.

called Wheat-Sheep and Pastoral Zones, but are insignificant in the High Rainfall Zone[9].

Implications arising from the results relate to suggestions to develop price or income stabilization policies for the beef industry in New South Wales and market information. For example, the imposition of herd size quotas may not achieve the implicit aim of controlling the level of beef supply without first effecting the impossible — namely controlling inventory response to seasonable conditions in all regions except the Coast and Northern Tablelands. In the absence of figures on regional female slaughterings, the results for inventory response suggest that the significance and magnitude of factors affecting beef supply are not uniform throughout New South Wales. Furthermore, a change in cow and heifer inventory in one region may lead to changes in the other regions and even, perhaps, changes in beef supply. Thus, the monitoring of inventory changes in that region may provide 'early-warning' signals in market information activities.

There is scope for further research to analyse other categories of beef cattle inventory and to evaluate alternative specifications of the expected prices and risks variables. Research in the latter area is needed to more adequately assess the usefulness of Just's adaptive risk model in the study of supply response in beef cattle and other livestock industries. Furthermore, the method adopted in this study requires the assumption that prices and risk in the current and more recent past periods do not have a significant effect on current inventory levels. A more realistic but perhaps complicating approach would be to impose some weighting scheme, other than zero weights, on these observations.

9. *See*, for example, Longmire *et al* (1979) and Davidson (1967) for descriptions of the zones.

References

A.B.S. (1979), *Handbook of Local Statistics 1979*, Cat. No. 1304.1, Australian Bureau of Statistics, Sydney.

ASKARI, H. and CUMMINGS, J. T. (1976), *Agricultural Supply Response: A Survey of the Econometric Evidence*, Praeger, New York.

BAIN, R. A. (1977), *An Econometric Model of the United States Beef Market*, Beef Research Report No. 20, Bureau of Agricultural Economics, Canberra.

BEHRMAN, J. R. (1966), 'Price elasticity of the marketed surplus of a subsistence crop', *Journal of Farm Economics* 48(4, I), 875–93.

BEHRMAN, J. R. (1968), *Supply Response in Underdeveloped Agriculture*, North Holland, Amsterdam.

BRENNAN, J. P. (1981), Some effects of risk on the supply of wheat in Victoria, 25th Annual Conference, Australian Agricultural Economics Society, Christchurch.

CAGAN, P. (1956), 'The monetary dynamics of hyper-inflations', in M. Friedman (ed.), *Studies in the Quantity Theory of Money*, University of Chicago Press, Chicago, pp. 25–117.

DAVIDSON, B. R. (1967), 'The economic structure of Australian farms', in D. B. Williams (ed.), *Agriculture in the Australian Economy*, Sydney University Press, Sydney, Ch. 2.

FISHER, B. S. and TANNER, C. (1978), 'The formulation of price expectations: an empirical test of theoretical models', *American Journal of Agricultural Economics* 60(2), 245–8.

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(2 & 3), 53–90.

FREEBAIRN, J. W. and RAUSSER, G. C. (1975), 'Effects of changes in the level of U.S. beef imports', *American Journal of Agricultural Economics* 57(4), 676–88.

JUDGE, G. G., GRIFFITHS, W. E., HILL, R. C. and LEE, T. C. (1980), *The Theory and Practice of Econometrics*, Wiley, New York.

JUST, R. E. (1974*a*), 'An investigation of the importance of risk in farmers' decisions', *American Journal of Agricultural Economics* 56(1), 14–25.

JUST, R. E. (1974*b*), *Econometric Analysis of Production Decisions with Government Intervention: The Case of the California Field Crops*, Giannini Foundation Monograph No. 33, University of California, Berkeley.

JUST, R. E. (1976), 'Estimation of a risk response model with some degree of flexibility', *Southern Economics Journal* 42(4), 633–43.

JUST, R. E. (1977), 'Estimation of an adaptive expectations model', *International Economic Review* 18(3), 629–44.

KLEIN, L. R. (1958), 'The estimation of distributed lags', *Econometrica* 26(4), 553–65.

KENKEL, J. L. (1974), 'Some small sample properties of Durbin's tests for serial correlation in regression models containing lagged dependent variables', *Econometrica* 42(4), 763–9.

LONGMIRE, J. L., BRIDEOAKE, B. R., BLANKS, R. H. and HALL, N. H. (1979), *A Regional Programming Model of the Grazing Industry*, Occasional Paper No. 48, Bureau of Agricultural Economics, Canberra.

LONGMIRE, J. L. and MAIN, G. W. (1979), An econometric model of the Australian beef industry, 22nd Annual Conference, Australian Agricultural Society, Sydney.

NERLOVE, M. (1958), *The Dynamics of Supply: Estimation of Farmers' Response to Price*, John Hopkins University Press, Baltimore.

REEVES, G. W. (1980), Some implications of the United States counter-cyclical beef import policy for the United States and Australia, 24th Annual Conference, Australian Agricultural Economics Society, Adelaide.

REEVES, G., LONGMIRE, J. and REYNOLDS, R. (1980), Australia's beef export supply for markets other than the U.S.A. and Japan: response to some exogenous shocks, Seminar on Australian Agriculture and Newly Industrialising Asia: Issues for Research, Research School of Pacific Studies, Australian National University, Canberra.

REUTLINGER, S. (1966), 'Short-run beef supply response', *Journal of Farm Economics* 48 (4, I), 909–19.

RYAN, T. J. (1977), 'Supply response to risk: the case of U.S. pinto beans', *Western Journal of Agricultural Economics* 2, 35–43.

TOMEK, W.G. and ROBINSON, K. L. (1972), *Agricultural Product Prices*, Cornell University Press, Ithaca.

TRAILL, B. (1978), 'Risk variables in econometric supply response models', *Journal of Agricultural Economics* 29(1), 53–61.

WEEKS, P. and REYNOLDS, R. (1981), 'Monitoring change in the Australian cattle herd', *Situation and Outlook, Meat*, Bureau of Agricultural Economics, Canberra.

WILSON, W. R., ARTHUR, L. M. and WHITTAKER, J. K. (1980), 'An attempt to account for risk in an aggregate wheat acreage response model', *Canadian Journal of Agricultural Economics* 28(2), 63–71.

Young, J. S. (1968*a*), 'Breeding patterns in commercial beef herds. 1. Herd performance in New South Wales', *Australian Veterinary Journal* 44(8), 350–6.
Young, J. S. (1968*b*), 'Breeding patterns in commercial beef herds. 2. Performance following the first joining', *Australian Veterinary Journal* 44(11), 487–92.