Research Note/Note de recherche

The Supply of Beef Cattle in Alberta: A Note on Modelling on a Provincial Basis

D.B. McGivern
XL Meats
Calgary, AB T2C 2H8

W.A. Kerr
Department of Economics
University of Calgary
Calgary, AB T2N 1N4

The supply of cattle is critically important to firms involved in the processing of beef. In an industry characterized by large capital investment, the volume of throughput is an important determinant of per unit costs. Further, as cattle are the major input in beef processing, information on their expected supply is essential for effective decision making. Hence, forecasts of beef cattle numbers are an integral part of a beef processing firm's planning process.

For both short-term and long-term planning within a beef processing firm, assumptions have to be made regarding the future supply of cattle available for slaughter. A long-term (that is, five years or more) forecast would be useful for the evaluation of projects which involve significant capacity expansion such as construction of new plants, enlargement of existing facilities, or renovations to increase plant efficiency. For example, a firm should consider carefully any expansion project in periods when cattle inventories and, subsequently, slaughter levels, may be declining over the next several years.

Models of beef supply, both Canadian and those developed for other countries, tend to be based on aggregated data for a relatively large market, usually

© Canadian Journal of Regional Science/Revue canadienne des sciences régionales, XVII:3 (Autumn/automne 1994), 413-425.
ISSN: 0705-4580 Printed in Canada/Imprimé au Canada

a country.[1] There are a number of reasons why modelling is undertaken at the national level. One is that there is a greater likelihood that reliable data will be available nationally. This allows the model builder the opportunity of correctly identifying all or most of the variables which significantly affect the market under investigation. This should lead to an efficient, properly specified model which will produce credible results. A second important reason is that models are often constructed to study the effects of policy and policy changes on a national basis.[2]

An industry or firm within a region can be affected by the actions of firms in other regions, as well as local policies in other regions. These effects can be more difficult to identify and quantify than in the case of national markets where policies of other countries and the actions of foreign industries tend to be more transparent. In the case of Canada, the most common method of regionalizing livestock industries in forecasting models has been to divide the country into eastern and western Canada.[3] This has been a convenient division for the purposes of analyzing policy impacts given that the structure of the industry differs considerably between the prairies and central Canada. Development of detailed provincial-level models has had only limited success (Kulshreshtha and Fisher 1972).

Beef processing firms in Canada tend to be characterized by single-plant operations. There are very few multi-plant, multi-region firms remaining. While a beef processing plant may be able to sell its meat and meat products in all regions of the country as well as in export markets, procurement of cattle tends to be very localized. Ward (1988) found that U.S. beefpackers purchase most of their cattle supply needs within a one hundred mile radius of a plant's location. The same general rule applies in Canada. Further, provincial government policies which may have significant impacts on local supplies, are not captured by more aggregate models. Hence, regionally aggregated forecasting models may not be particularly useful for livestock processors' planning purposes as "supply response in different geographic regions may vary because of local production possibilities and economic conditions" (Martin and Haack 1977: 29).

1. See, for example, Gordon (1983), Kulshreshtha (1976), Kulshreshtha and Wilson (1974) and Tryfos (1974) for Canada; Antonovitz and Green (1990), Rucker et al. (1984), Arzac and Wilkinson (1979) for the U.S.; Harrison (1982) for Australia and Jarvis (1974) for Argentina.
2. It is also important to note that regional models of demand for beef are less useful for firms in the beef industry. Firms operate in an integrated North American market for processed beef with prices determined on a North American basis. Hence, existing price forecasting services are sufficient for planning purposes. Further, as there are long, biologically determined lags between the point in time when beef producers make decisions based on price information and when animals are presented for sale, current prices at the point in time when animals are ready for slaughter have no effect on current cattle supply.
3. See for example Klein (1979), Moschini and Meilke (1987) and Martin and Haack (1977).

The major reason why provincial-level modelling of slaughter cattle supplies has not taken place is that little reliable provincial-level data exist regarding international and interprovincial movements of both feeder and slaughter cattle. These "leakages" can be considerable (for example, see Table 1) but it is not possible to model them explicitly. Since the failure to explicitly model both international and interprovincial movements of cattle would greatly reduce the accuracy of provincial-level models, it would invalidate the entire modelling exercise.

The exports of Canadian slaughter cattle are considerable and growing. However, prior to 1987, Agriculture Canada reported exports based on compilations collected at selected ports of exit. These data showed British Columbia to be the largest province in terms of exporting slaughter cattle to the U.S. In fact, most of these cattle were of Alberta origin, only being transported through B.C. ports of exit. Agriculture Canada now reports B.C. and Alberta exports on the basis of province of origin, but the data are limited to only the last few years. Over time, a consistent set of export data will be acquired which will have sufficient observations for estimation encompassing a complete cattle cycle of approximately ten years. However, the Statistics Branch of Alberta Agriculture, through the use of Brands Inspection data, has consistently reported exports to the U.S. at significantly higher levels than Agriculture Canada, even in recent years. The discrepancy between the data of these two agencies has not been resolved.

There is also a considerable degree of interprovincial movement of cattle. Depending upon differences in relative prices among regions, movement can occur into and out of a province. For example, Alberta Agriculture (1991) reported 1990 sales of Alberta slaughter cattle to Saskatchewan destinations at 47,586 head. At the same time, Saskatchewan Agriculture and Food (1991) estimated marketings of Saskatchewan slaughter cattle to Alberta at 48,530. The comparable figures for 1989 were 61,694 head of Alberta slaughter cattle sold to Saskatchewan and 37,200 head of Saskatchewan slaughter cattle sold to Alberta. There are also shipments of Alberta slaughter cattle to Ontario, although these levels have declined in recent years. Further, interprovincial movements of feeder cattle and calves take place. Again, these data are often limited and their accuracy suspect.

The question which this note attempts to answer is whether it is possible to develop a provincial-level model of cattle supply that provides forecasts of sufficient accuracy to be useful for firm-level planning purposes, given that it is not possible to explicitly model interprovincial and international movements of cattle.

TABLE 1 Annual Cattle Slaughter and Exports (1987-1993)

Year	Cattle Slaughter (000's)	Live Cattle Exports (000's)	Exports as a % of Slaughter
1987	1135.1	103.1	9.1
1988	1206.2	199.2	16.5
1989	1271.3	183.0	14.4
1990	1312.7	196.9	15.0
1991	1230.3	205.5	26.5
1992	1338.9	358.8	26.8
1993[a]	1406.5	372.1	26.5

Source: Agriculture Canada, Livestock Market Review.
a. Preliminary.

The Model

The model provides estimates of annual slaughter cattle supplies for Alberta. Thirteen equations constitute the model, including seven cattle inventory equations, four cattle slaughter equations and two cattle price equations. In addition, four exogenous variables are required (price of barley, prime interest rate, U.S. slaughter steer price and the Canada/U.S. exchange rate).

The producer decision-making process was simulated with the use of expected prices, leading to the inclusion of lagged price variables (through an adaptive expectations model) which had the expected sign on the estimated coefficient and showed strong influences on future production. This model specification assumes that producer expectations are based on past price and profitability levels. Lagged dependent variables entered several of the equations characterizing the biologically determined production lags observed in the industry.

Dummy variables were included to account for government programs or natural disasters which have affected the supply of cattle. The effects of the federal government's Lower Inventories for Tomorrow (LIFT) grain policy of the early 1970s, the U.S. meat price freeze initiated in 1973 and the severe drought in Alberta in 1985 were captured in this way. Of particular importance is the Alberta government's Crow Benefit Offset Program which has the intent of increasing the number of animals finished in Alberta and, hence, altered the distribution of cattle within western Canada. The effects of this program could not be included in models which are less geographically disaggregated. The effect of export movements was implicitly modeled through the inclusion of the price of U.S. slaughter steers in the model. The U.S. price provides the incentive for movements of slaughter cattle out of Alberta reducing supplies when

U.S. prices are high. A complete discussion of the data, development of the model and results can be found in McGivern (1992).

The current supply of beef cattle available for slaughter is the result of production decisions made by farmers in the past. For example, a farmer's decision to increase his production, has, as its first step, a reduction in the sale of heifers - young unbred females. This reduces the number of cattle available for slaughter. The additional heifers retained in the herd are bred. After a nine month gestation period, the calves from the additional heifers are born and then must grow to maturity before they are slaughtered. Hence, the process of increasing output may take up to four years after the original decision to expand production is taken. Consequently the decision to breed additional heifers is independent of current prices since the farmer is committed to a production process. Decisions to downsize herds also work their way through to a reduction in cattle supplies only with a lag. The biological constraints on changes to the production processes in the beef cattle industry are the underlying cause of the well-known cattle cycles lasting eight to ten years.

The model of beef cattle supply in Alberta is designed to capture these complex lags and the interactive effects of various sources of supply. There are three major sources of slaughter cattle -- steers, heifers and cows and bulls. Steers are produced only for meat. Heifers can be slaughtered for meat or retained in the herd for breeding purposes. Cows and bulls are mature animals from the breeding herd which are only offered for slaughter at (or near) the end of their productive breeding life. Separate supply equations are estimated for steers, heifers and bulls and cows and summed to obtain total cattle available for slaughter in Alberta. The predictive equation for Alberta heifer slaughter (Equation 9, Table 2), for example, is a function of the inventory of calves in Alberta, profit, a dummy variable for an important government program[4] and the lagged dependant variable. The current (January 1) inventory of calves is the pool of animals from which heifers for slaughter are drawn for the year. An increase in inventory will lead to increased heifers for slaughter. Profitability, proxied by the ratio of steer price to barley price, would be expected to impact negatively on heifer slaughter as farmers hold back additional heifers for breeding purposes to take advantage of higher prices expected in the future.

The model provides an estimate of the important variable in the Alberta heifer slaughter equation, inventory of calves (Equation 4, Table 2). Alberta heifer slaughter is a function of lagged prices for steers and barley and lagged cow inventory. As the breeding herd (cow inventory) increases, more heifers will be born and, subsequently, available for slaughter. The Alberta cow inventory arises from two sources (Equation 7, Table 2) -- the number of beef

4. The federal government's Lower Inventories For Tomorrow (LIFT) program encouraged farmers to increase their herds.

TABLE 2 Alberta Slaughter Cattle Supply Model

	N	Mean	$\bar{R}^2$	DW	Dh	AIC	SE	P
1. Alberta Beef Cow Inventory $ABC_t = 113.695 + 1.057\ ABC_{t-1} + 0.629\ ATBH_{t-1} - 1.297\ ACBS_{t-1} + 1.124\ PCVS_{t-3}$ (2.26) (8.97) (2.02) (-4.78) (3.06) $-1.534\ PBLY_{t-3} - 7.926\ INT_{t-1}$ (-5.32) (-2.44)	25	1347.4	0.96	1.57	1.07	34.81	31.00	1967-91
2. Alberta Total Beef Heifers $ATBH_t = 0.535\ ATBH_{t-1} + 0.124\ ABC_{t-1} + 0.499\ PCVS_{t-1} - 0.369\ PBLY_{t-1} - 0.294\ PBLY_{t-3}$ (3.04) (2.65) (2.99) (-2.12) (-1.66) $+ 33.842\ D71 + 54.504\ D72 + 30.594\ D73$ (1.90) (3.14) (1.63)	25	329.6	0.87	2.54	1.38	18.03	15.88	1967-91
3. Alberta Yearling Steer Inventory $ASTRS_t = -77.393 + 0.430\ ASTRS_{t-1} + 0.276\ ABC_{t-1} + 1.123\ PSTR_{t-1} - 7.056\ TIME$ (-3.07) (4.61) (6.03) (2.33) (-4.37)	31	352.0	0.95	1.55	1.45	18.97	17.63	1961-91
4. Alberta Calf Inventory $ACVS_t = 0.870\ ATC_{t-1} + 1.829\ PCVS_{t-2} + 2.219\ PCVS_{t-3} - 3.884\ PBLY_{t-1} + 94.669\ CBOP_t$ (50.99) (2.52) (2.78) (-8.33) (3.36)	27	1271.1	0.90	2.24	N/A	45.18	41.59	1965-91
5. Alberta Dairy Cow Inventory $ADC_t = 82.574 + 0.435\ ADC_{t-1} + 1.354\ ADH_{t-1} - 2.513\ TIME$ (4.48) (4.49) (6.18) (-5.19)	31	181.3	0.99	1.57	1.44	5.13	4.83	1961-91
6. Alberta Dairy Heifer Inventory $ADH_t = 0.955\ ADH_{t-1} + 0.093\ TIME$ (49.54) (2.03)	31	44.3	0.89	1.61	1.10	2.74	2.63	1961-91
7. Alberta Total Cow Inventory $ATC_t = ABC_t + ADC_t$	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1967-91

	N	Mean	$\bar{R}^2$	DW	Dh	AIC	SE	P
8. Alberta Steer Slaughter $ASTRSL_t = -286.312 + 0.464\ ASTRSL_{t-1} + 0.406\ ASTRS_t + 0.337\ ACVS_t$ (-3.56) (4.17) (3.13) (4.57) $+ 48.399\ PROFIT_{t-1} + 69.535\ D70 + 55.833\ D71 + 75.210\ D72 - 62.637\ D74$ (1.43) (2.34) (1.83) (2.57) (-2.16)	27	615.11	0.93	2.32	1.13	31.20	27.38	1965-91
9. Alberta Heifer Slaughter $AHFRSL_t = 0.779\ AHFRSL_{t-1} + 0.146\ ACVS_t - 118.237\ PROFIT - 58.174\ D73$ (16.52) (7.52) (-5.53) (-2.20)	27	346.8	0.95	1.60	1.04	27.36	25.56	1964-90
10. Alberta Cow and Bull Slaughter $ACBS_t = 0.185\ ACBS_{t-1} + 0.122\ ATC_t - 0.761\ PCVS_t + 0.382\ PBLY_t + 44.629\ D85$ (1.79) (7.31) (-5.77) (2.47) (2.48)	27	197.6	0.81	1.79	0.55	18.05	16.61	1964-90
11. Alberta Total Cattle Slaughter $ACTLS_t = ASTRSL_t + AHFRSL_t + ACBS_t$	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1964-90
12. Alberta Slaughter Steer Price $PSTR_t = 0.959\ PSTRUS + 8.50\ D74$ (150.86) (5.57)	32	51.3	0.99	1.52	n/a	1.56	1.52	1960-91
13. Alberta Feeder Steer Calf Price $PCVS_t = 2.805 + 1.753\ PSTR_t - 0.355\ PBLY_t - 1.049\ INT_{t-1}$ (1.32) (33.16) (-8.51) (-2.96)	27	62.9	0.99	1.43	n/a	3.86	3.61	1964-90

N - Number of observations;
Mean - Mean value of the dependent variable;
$\bar{R}^2$ - Adjusted R-square;
D-W - Durbin-Watson statistic;
Dh - Durbin's h statistic;
AIC - Akaike Information Criterion;
SE - Standard error;
P - Period of estimation;
n/a - Not applicable.

cows and the number of dairy cows. The model provides separate equations for estimating the number of beef cows (Equation 1, Table 2) and the number of dairy cows (Equation 5, Table 2). Each is specified to reflect the biologically determined lags in cattle production. Hence, the model is recursive building up from the technical foundations of beef cattle production. A similar bottom up approach is taken for steer supply and bull and cow supply. The recursive structure of the model allowed estimation to be undertaken using Ordinary Least Squares (OLS).[5] The equations were found to be either free of serial correlation or the test for serial correlation was inconclusive.

The model is summarized in Table 2. For each equation, the t-values for the coefficients are shown in brackets. A summary of statistics is provided for each equation, including the number of observations (N), mean value of the dependent variable (MEAN), adjusted R-square ($\bar{R}^2$), Durbin-Watson statistic (D-W), Durbin's h statistic (Dh),[6] Akaike Information Criterion error statistic (AIC),[7] the standard error of the regression (SE) and the data period used for estimation (P). A complete list of the variables can be found in Appendix I.

Simulation Results

The primary motivation for modelling cattle supply in Alberta was to build a model which would provide useful forecasts for a beef processor in Alberta. To test the model's forecasting ability, *ex post* forecasts for the period 1982 through 1991 were produced. This was accomplished by considering 1981 as the last year in which actual data were available. From 1982 onward, the simulation relied upon estimates made by the equations themselves for endogenous inputs to future years. Actual values were used for the model's exogenous variables. A ten-year period was chosen as this length of time would cover the period of a "typical" cattle cycle. Five different tests are performed on the simulation (Pindyck and Rubinfeld 1981). The first measure used is the root-mean-square simulation error (RMS error) which measures the degree to which a simulated variable deviates from its actual time path. A second measure is the RMS percent error which measures the deviation of a simulated variable in percent terms. The mean simulation error and the mean percent error were also calculated. All of these values are compared to the mean value of the dependent variable. The final measure employed in evaluating the *ex post* simulations was Theil's inequality coefficient (U).

5. See, Gujarati (1988: 596-599).
6. In the case of single-equation models containing a lagged dependent variable, the Durbin-Watson statistic is not valid for detecting the possible presence of serial correlation. The D-W statistic will be biased toward 2 even if the errors are serially correlated. Pindyck and Rubinfeld (1981) suggest the use of Durbin's h statistic for equations with one or more lagged endogenous variable. A test for positive serial correlation at the 5% level would take h > 1.645 as the critical value.
7. As discussed by Harvey (1990: 177), the selection of models can be done by "compar(ing) the maximized values of their respective likelihood functions". Where the number of parameters are the same, the decision will lead to the model with the highest R-square. The Akaike Information Criterion has the advantage of correcting for the number of parameters estimated, allowing for a comparison of models with different numbers of parameters.

The test results of the *ex post* forecast are shown in Table 3. The error statistics and U coefficients for the equations are relatively small, indicating a good simulation fit. Only three equations (ASTRS, ASTRSL and ACBS) have RMS percent errors greater than seven percent. The forecast for total cattle slaughter for 1982 through 1991 exhibits a RMS error of 78,131 versus a mean value of 1,244,616 head. The RMS percent error is 6.24 percent. The mean error is -51,479 and the mean percent error is -4.12 percent. The U coefficient is 0.032. Thus, the model performs reasonably well in simulating total cattle slaughter. Total Alberta cattle slaughter is compared to the *ex post* forecast in Figure 1.

With the equations demonstrating a good statistical fit and good simulation performance, an *ex ante* forecast was performed for the five-year period 1992 through 1996. The exogenous variables used in the *ex ante* forecasts were taken directly from Agriculture Canada's Medium Term Outlook (Agriculture Canada 1992). A casual comparison was made with the medium term forecast of Agriculture Canada (1992). A rigorous comparison could not be done, nor be valid, as the medium term outlook is based on the forecasts of a national-level model. However, the direction in beef cattle inventory and cattle slaughter are very similar, although the magnitude of the year-to-year changes for the Alberta model are higher than the Agriculture Canada forecast for the nation. The beef cattle inventory for Canada is expected to peak in 1995 and show a modest decline in 1996 while the projections for Alberta suggest continued but slowing growth. It could well be that a region such as Alberta could continue to show a discrete amount of growth when the national herd has begun to contract. The timing of the turns in the cattle cycle can differ in one province in comparison to the country as a whole. In fact, the Alberta cattle herd began expansion in the late 1980s prior to expansion of the national herd. Being able to anticipate turns in the cattle cycle is central to the planning activities of beef processors.

Conclusion

The modelling of beef cattle supplies on a provincial level has not generally been undertaken in Canada. The major forecasting models are based either on national aggregates or divide the country into eastern and western regions. The major reason for the lack of modelling effort at a more disaggregated level is lack of reliable data on international and interprovincial movements of cattle

TABLE 3 Test Statistics for Ex Post Simulation

Variable	Mnemonic	Actual Mean	rms Error	rms % Error	Mean Error	Mean % Error	Theil's U Coefficient
Beef Cow Inventory	ABC	1365.4	69.50	5.24	-58.60	4.40	0.03
Total Beef Heifer Inventory	ATBH	322.3	18.09	5.63	-15.79	-4.88	0.03
Calf Inventory	ACVS	1360.7	58.43	4.03	-37.39	-2.62	0.02
Yearling Steer Inventory	ASTRS	337.2	31.12	9.93	-18.41	-5.96	0.05
Dairy Cow Inventory	ADC	135.2	4.59	3.46	2.55	1.99	0.02
Dairy Heifer Inventory	ADH	45.5	2.18	4.78	1.45	3.22	0.02
Total Cow Inventory	ATC	1500.7	65.30	4.50	-56.05	-3.82	0.02
Slaughter Steer Price	PSTR	79.49	1.61	1.96	0.49	0.60	0.01
Feeder Steer Calf Price	PCVS	96.56	4.78	5.10	0.79	1.21	0.02
Steer Slaughter	ASTRSL	654.4	55.54	7.95	-39.95	-5.83	0.04
Heifer Slaughter	AHFRSL	403.7	23.61	5.98	1.19	0.48	0.03
Cow and Bull Slaughter	ACBS	186.5	19.16	10.64	-12.71	-6.90	0.05
Total Cattle Slaughter	ATCSL	1244.6	78.13	6.24	-51.48	-4.12	0.03

which prevents explicit modelling of these movements. As firms in the beef processing industry tend to source supplies of cattle locally, forecasts based on highly aggregated geographic areas may not be particularly useful for business planning. Long-range planning is particularly important in beef processing given the long lags associated with cattle production and the importance of plant throughput to per-unit costs.

The model of Alberta cattle supply presented in this paper performs sufficiently well in a forecasting capacity to suggest that it would be useful for business planning. It is hoped that the results presented in this note are sufficiently encouraging that interest in modelling beef supply in other provinces may be stimulated. Modelling the Alberta industry may prove easier than other provinces, however, due to the size and importance of the Alberta industry to the Canadian industry. In less important beef producing provinces, the inability to explicitly model extra provincial movements of cattle may introduce unacceptable levels of error into a model's forecasts.

Appendix 1

List of Variables

ABC	-	the inventory of Alberta beef cows;
ACBS	-	the number of cows and bulls slaughtered in Alberta;
ACTLS	-	total cattle slaughter in Alberta;
ACVS	-	the inventory of calves under one year old in Alberta;
ADC	-	the inventory of Alberta dairy cows;
ADH	-	the inventory of Alberta dairy heifers;

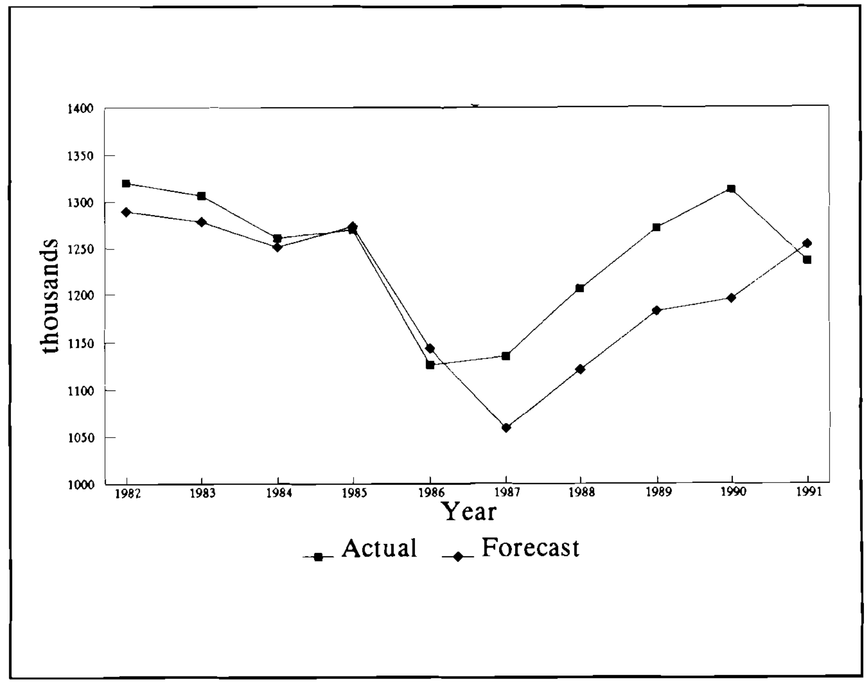

FIGURE 1 Alberta Total Cattle Slaughter

AHFRSL	-	Alberta heifer slaughter;
ASTRS	-	the inventory of yearling steers in Alberta;
ASTRSL	-	Alberta steer slaughter;
ATC	-	the inventory of total beef and dairy cows in Alberta;
ATBH	-	the inventory of total beef heifers in Alberta;
CBOP	-	dummy variable for Alberta Government Crow Benefit Offset Program;
D70	-	dummy variable for Federal Government's Lower Inventories for Tomorrow (LIFT) program - 1970;
D71	-	dummy variable for Federal Government's Lower Inventories for Tomorrow (LIFT) program - 1971;
D72	-	dummy variable for Federal Government's Lower Inventories for Tomorrow (LIFT) program - 1972;
D73	-	dummy variable for U.S. Government meat price freeze - 1973;
D74	-	dummy variable for U.S. Government meat price freeze - 1974;
D85	-	dummy variable to capture the effect of severe drought in Alberta - 1985;

INT	-	prime interest rate;
PBLY	-	price of off-board barley in Alberta;
PCVS	-	price of Alberta feeder steer calves;
PROFIT	-	a proxy for profit defined as the ratio of slaughter steer prices to barley prices;
PSTR	-	price of Alberta slaughter steers;
PSTRUS	-	the price of U.S. slaughter steers in Canadian dollars;
TIME	-	a time trend.

References

Agriculture Canada. 1992. *Medium Term Outlook - January 1992*. Ottawa.

Alberta Agriculture. 1991. *Interprovincial and Export Sales, Cattle, Alberta, 1990*. Edmonton: Statistics Branch.

Antonovitz, F., and R. Green. 1990. "Alternative Estimates of Fed Beef Supply Response to Risk", *American Journal of Agricultural Economics*, 72: 475-487.

Arzac, E.R., and M. Wilkinson. 1979. "A Quarterly Econometric Model of United States Livestock and Feed Grain Markets and Some of its Policy Implications", *American Journal of Agricultural Economics*, 61: 297-308.

Gordon, D.V. 1983. "Negative Supply Response and the Role of Price Expectations in a Two-Period Model of Cattle Production", *Canadian Journal of Agricultural Economics*, 31: 184-195.

Gujarati, D.N. 1988. *Basic Econometrics*. New York: McGraw-Hill.

Harrison, I. 1982. "Beef Cow Inventory Response: An Attempt to Apply the Adaptive Risk Model", *Review of Marketing and Agricultural Economics*, 50: 165-1979.

Harvey, A.C. 1990. *The Econometric Analysis of Time Series*. Hertfordshire: Philip Allen.

Jarvis, L. 1974. "Cattle as Capital Goods and Ranchers as Portfolio Managers: An Approach to the Argentine Cattle Sector", *Journal of Political Economy*, 82: 489-520.

Klein, K.K. 1979. "Analysing Absolute vs. Squared Deviations for Predicting Western Regional and National Hog Supplies in Canada", *Canadian Journal of Agricultural Economics*, 27: 74-84.

Kulshreshtha, S.N. 1976. "An Analysis of Canadian Cattle Supply Using Polynomial Distributed Lags", *Canadian Journal of Agricultural Economics*, 24: 1-14.

Kulshreshtha, S.N., and R.G. Fisher. 1972. "Predicting Regional Net Marketing of Beef Cattle in Saskatchewan", *Canadian Journal of Agricultural Economics*, 20: 90-97.

Kulshreshtha, S.N., and A.G. Wilson. 1974. "Long Swing Hypothesis for Cattle and Hog Output and Prices in Canada: An Application of Spectral Analysis", *Canadian Journal of Agricultural Economics*, 22: 12-25.

Martin, L.J., and R. Haack. 1977. "Beef Supply Response in North America", *Canadian Journal of Agricultural Economics*, 25: 29-47.

McGivern, D.B. 1992. "An Econometric Model of Beef Supply Response in Alberta". M.Ec. Dissertation. University of Calgary.

Moschini, G., and K.D. Meilke. 1987. "An Analysis of Spatial Price Differences in the North American Livestock Sector", Agriculture Canada Working Paper 7/87, Ottawa.

Pindyck, R.S., and D.L. Rubinfeld. 1981. *Econometric Models and Economic Forecasts*. New York: McGraw-Hill.

Rucker, R.R., O.R. Burt, and J.T. La France. 1974. "An Econometric Model of Cattle Inventories", *American Journal of Agricultural Economics*, 66: 131-144.

Saskatchewan Agriculture and Food. 1991. *Saskatchewan Cattle Marketing Report for the Year 1990*. Regina: Statistics Section, Economics Branch.

Tryfos, P. 1974. "Canadian Supply Functions for Livestock and Meat", *American Journal of Agricultural Economics*, 56: 107-113.

Ward, C.E. 1988. *Meatpacking Competition and Pricing*. Blacksburg, Va.: Research Institute on Livestock Pricing.