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Suggested citation format:

Abidoye, B., and J. D. Lawrence. 2009. "A Limited Information Bayesian Forecasting Model of the Cattle SubSector." Proceedings of the NCCC-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management. St. Louis, MO. [http://www.farmdoc.uiuc.edu/nccc134].

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Paper presented at the NCCC-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management
St. Louis, Missouri, April 20-21, 2009

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Practitioner's Abstract

The first step towards forecasting the price and output of the cattle industry is understanding the dynamics of the livestock production process. This study follows up on the Weimar and Stillman (1990) paper by using data from 1970 to 2005 to estimate the parameters that characterizes the cattle output supply. The model is then used to estimate forecast values for the periods 2006 and 2007. Bayesian limited information likelihood method is used to estimate the parameters when endogeneity exists between these variables. The forecasting ability of the model for a two-step ahead forecast for majority of the variables are relatively good and test statistic of the forecast are reported.

Keywords: Cattle, Bayesian, forecasting, Inventory, Slaughter

Introduction

Understanding the dynamics of livestock supply and prices by policy makers is essential given the information it carries. Knowledge of the level of supply of cattle at a future time can help in the stabilization of the market. This requires adequate characterization and estimation of the effect of each component of the production process on the total output of the subsector. However, because of the dynamic and simultaneous relationships that exist in the production and supply of cattle, forecasting and inference can be challenging.

Numerous studies including those of the USDA has proposed different models to forecast the livestock sector. Many of these studies consider partial models and ignore or assume the other side of the market is exogenous. Studies that modeled both sides of the market include Chavas (1978), Westcott (1986) and Weimar and Stillman (1990). Weimar and Stillman considered cross-correlation error in the estimates of their parameters in contrast to other studies. However, the forecasting ability of some of these studies in terms of out of sample predictions (especially for more than one step ahead forecast) has been questioned.

This study is part of a larger project that seeks to explore the best forecast of the output and price of the cattle sector by appropriately modeling the relationship that exists between the structural variables. The objective of this paper is not only to revise the Weimar and Stillman paper by looking at a larger and current time frame but to also make use of the Bayesian Method of Moment methodology that outperforms the two-stage least square methodology when endogeneity is not weak. We model the cattle subsector as a system of simultaneous equation.

Model

Weimar and Stillman used thirteen equations to characterize the cattle sector by allowing for possible interactions between the structural models. These equations represent the main components of the production flow in the cattle sector. The first set of equations model the inventory of cattle in a time period (Beef Cow Inventory, Milk Cow Inventory, Steer Inventory, other heifer inventory and Bull Inventory). The second set includes corresponding slaughter equations; and lastly replacement inventory (Beef Heifer Replacement and Milk Heifer Replacement).

The three set of variables are interrelated based on the production process that characterizes the beef and cattle industry from breeding to slaughter. We will expect that an increase in the cost of feeding cattle will result in higher slaughter and or lower need to hold beef cows other things been equal. All these interactions are incorporated into the structural model. In this study, we only focus on the supply side of the sector. The inventory variables depend on previous periods return from holding those inventories and possible cost of holding those inventories. Slaughter variables on the other hand depend on the level of inventory and current period return.

The model and variables are similar to those presented in Weimar and Stillman. Specifically, the Beef Cow Inventory is characterized as a function of cow cash returns lagged two periods, heifer slaughter inventory as an indicator of possible replacement, the cost of feeding the cows proxied by the price of hay and a feedback of the level of beef cow inventory in the previous period. Milk Cow Inventory on the other hand is a function of the stock of heifer in the previous period available as replacements for the milk cows and a lagged milk cow inventory. Calf crop – the number of calves born in a period, is specified to be a function of cow stock in that period and the returns from the cow lagged two periods. This captures the fact that the production process needs time to adjust to changes in output. The heifer replacements depend on the cow inventory and the cost of feeding while the slaughter variables depend on the inventory level and the residual calf inventory (Calf crop – calf slaughter). Finally, the average beef dressed weight is assumed to be a factor of cow slaughter in that period and the price of hay.

METHODOLOGY

The econometric analysis in this section is two-fold. First, we seek to consistently estimate the parameters of the model described above by taking into consideration issues of endogeneity and correlation between the different production processes. This will then be used to make inference and forecast future values of cattle supply.

In contrast to the two stage least squares (2SLS) methodology used in Weimar and Stillman, we adopt the Bayesian Method of Moment estimator. Specifically, we consider a limited information formulation of the variables described above:

$$y_1 = Y_2\beta + X_1\gamma + u$$
$$Y_2 = X_1\pi_1 + X_2\pi_2 + V$$

Where y_1 is a Tx1 vector of endogenous variable of interest and Y_2 is a T x (m-1) matrix of endogenous variables. X_1 and X_2 are exogenous variables included in the structural equations. u and V are matrix of random disturbances to the system.

The Bayesian method of moments approach is in the class of double K-class estimator and applies the principle of maximum entropy to generate optimal estimates. The set of K-class estimator for the structural coefficients above is given by:

$$\begin{pmatrix} \hat{\beta} \\ \hat{\gamma} \end{pmatrix} = \begin{pmatrix} Y_2'Y_2 - K_1\hat{V}_1'\hat{V}_1 & Y_2'X_1 \\ X_1'Y_2 & X_1'X_1 \end{pmatrix}^{-1} \begin{pmatrix} (Y_2 - K_2\hat{V}_1)'y_1 \\ X_1'y_1 \end{pmatrix}$$

Where $\hat{V}_1 = (I - X(X'X)^{-1}X')Y_2$; $K_1 = 1 - k/(T-k)$; and $K_2 = 1 - (1-\omega)k/(T-k)$ with $0 \le \omega \le 1$. The above estimator is a generalization of the 2SLS estimator where $K_1 = K_2 = 1$.

The other equations without endogenous variables were estimated using Bayesian methodology that consistently estimates the parameters for those equations. Some of these variables include auto correlated error terms and autoregressive processes. The procedure we followed to estimate those parameters are similar to those outlined in Koop, Poirier ad Tobias (2007) (pp. 198 and 298).

For predictive purposes, we make use of the properties of the estimators to make two-step-ahead forecast. For cases where the dependent variable is of the autoregressive form, the predictive density of more than one-step-ahead forecasts does not have an analytical form. We therefore follow the procedure outlined in Bauwens, Lubrano and Richard (1999, pp. 137) to calculate the moments of the two-step-ahead forecast for all the variables in our model.

We estimate the Theil's U statistic to assess the predictive accuracy of our forecasting model. This statistic avoids the scaling problem that plagues both the root mean squared error and mean absolute error statistics. Low values of the U statistic indicate a good predictive power of our forecast.

DATA

Annual data from 1970 to 2007 is used in our analysis. The use of a relatively large data will also improve the parameter estimates and out of sample prediction. Data are collected from different sources including the National Agricultural Statistics Service (NASS) of the USDA, Livestock Marketing Information Center (LMIC), and Economic Research Service (ERS).
For the estimation part of the data, we use data from 1970 to 2005 and out-of-sampling predictions were validated using 2006/2007 data.

RESULTS

Table 1 presents the results for the parameter estimates and standard deviation for each variable of interest. It also includes the two years predicted values for all the variables and validation statistics.

Beef Cow Inventory: This is modeled as an autoregressive variable of order one with other exogenous variables included in the model. The results show that the higher the returns from the cow the higher the inventory that will be held. Also, the stock momentum is about 87% for cow inventory. This implies that, other things been equal, out of one percentage point of beef cow inventory in a year, 0.87 of a percentage point will be retained. Hay price also negatively affects the stock as expected.

The two-step-ahead forecasts are also presented in the table. The model performed well in predicting the values of the inventory for the two years as shown by the Theil's U statistic. Also, the estimates are within one standard deviation of the true values for those years.

Milk Cow Inventory: This is also assumed to be autoregressive of order one with lagged values of milk heifer replacement as an exogenous variable. Though the effect of milk heifer replacement has a distribution that is massed around zero, the result shows that higher milk heifer replacement stock results in higher stock of milk cow inventory at a particular time. The turnover of the stock of milk cow is not that high between periods as shown by the effect of the lagged value on present stock. The value of the two-step-ahead forecast is also presented with the Theil's U statistic.

Calf Crop: The results of the calf crop equation also has the expected signs with beef cow inventory having a positive effect on calf crop and higher cow cash returns lagged two periods resulting into more calf breeding. The forecast values are also presented in the table for 2006 and 2007. The Theil's U statistics is also close to zero.

Heifers, Steers and Bulls (< 500 lbs): This is estimated as a function of the difference between last period's calf crop and calf slaughter and last periods hay price. Hay price is expected to reduce the inventory of heifers, steers and Bulls because it becomes more expensive to keep than. The higher the calf crop retained in the previous period the higher the number of heifers, steers and bulls inventory that are less than 500lbs. The forecast for the two periods for this variable did not do as good as the other variables with the Theil's U statistic of 0.13.

Other heifer inventory was also estimated with cow cash return and hay prices lagged one period. The residual calf inventory was also included in the regression. The results show that as hay price rises, heifers on feed will be increased while higher cow cash returns will make this option less attractive favoring keeping heifers for replacements.

The bull inventory is estimated as a function of cow inventory given the nature of the production process. Bull slaughter is also modeled as a function of cow slaughter. The parameters are of the expected signs. While the prediction for bull inventory was relatively good, the Theil's statistic for the Bull slaughter was higher.

Beef cow slaughter is a function of the stock of beef cow at that period, heifer replacement, cow cash return and hay prices. The results show that when the cow cash return is high, more cows are slaughtered while higher hay prices increases the cost of feeding the cows thereby leading to higher slaughter. Milk cow slaughter on the other hand depends on the price of milk and also the inventory. We could not conclude that the price of milk was an important determinant of milk cow slaughter. The average beef dressed weight is modeled as a function of the price of hay and total cow slaughter.

TOPICS FOR FURTHER RESEARCH

Research into the area of modeling the relationship between the production processes through the use of vector autoregressions (VAR) will be explored. As described in Diebold (1998) and Stock and Watson (2001) and numerous other studies, VAR models can perform better in estimating the relationship between variables and most especially does better in terms of forecasting ability. We will compare the forecasting power of using a VAR model with a combination of some structural parameters. VAR models can also allow for more feedback between the variables which can play a big role in our application.

SUMMARY AND CONCLUSIONS

This study estimates an annual structural model of the cattle sector for the period 1970 to 2005. The results from this model is then used to make predictions of the future values of the stock and slaughter numbers for the components of the cattle production process for the period 2006 and 2007. This study follows the work of Weimar and Stillman (1990) with various modifications. The first contribution is in terms of the data set used which is more current and span more periods than that of Weimar and Stillman. Secondly, the model parameters are estimated using Bayesian method of moment that has been shown to outperform the 2SLS methodology used in the Weimar and Stillman paper when endogeneity is not weak. The forecasting ability of the model for a two-step-ahead forecast is shown to be relatively good.

Further research will be done in the area of modeling the sector in the form of vector autoregressions to compare the forecasting ability of these models. Also, extending the forecast horizon to more than two periods will be informative for policy makers and stake holders.

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Table 1-Estimation Results for Annual Forecasting Model for the cattle subsector using data from 1970 to 2007

Parameter	Estimate	Standard Error
Beef Cow Inventory =		
Intercept	13644	(3226)
Cow cash return$_{t-2}$	12.569	(4.7776)
Cow cash return$^{2}_{t-2}$	-0.031	(0.035)
(Heifer Slaughter/heifer inventory)$_{t-1}$	-14,824	(2424.70)
Hay Price$_{t}$	-16.802	(8.2705)
Beef Cow Inventory$_{t-1}$	0.865	(0.056)
Beef Cow Inventory (2006)	33521	630.52
Beef Cow Inventory (2007)	34042	3410.80
Theil U statistic	0.03	
Milk Cow Inventory =		
Intercept	110.62	573.3
Milk heifer replacement$_{t-1}$	0.049	0.12
Milk cow inventory$_{t-1}$	0.961	0.032
Milk Cow Inventory (2006)	8963.80	171.86
Milk Cow Inventory (2007)	8974	172.34
Theil U statistic	0.014	
Calf Crop =		
Intercept	-47.944	1446.30
Beef cow inventory$_{t}$	0.4596	0.1086
Milk cow inventory$_{t}$	1.78	0.2371
Beef Heifer Replacement$_{t}$	1.1254	0.3794
Cow cash returns$_{t-2}$	4.1681	2.2598
Calf Crop (2006)	37620	766.58
Calf Crop (2007)	38039	769.05
Theil U statistic	0.013	
Beef Heifer Replacement =		
Intercept	2092.90	1441
Beef Cow Inventory$_{t}$	0.2178	0.0305
Hay price$_{t-1}$	4.3678	5.872
Beef heifer replacement (2006)	5599.9	452.07
Beef heifer replacement (2007)	5743.30	460.05
Theil U statistic	0.04	

Milk Heifer Replacement =		
Intercept	434.60	529.89
Milk Cow Inventory$_t$	0.24091	0.0392
Milk price$_{t-1}$	102.84	13.173
Milk heifer replacement (2006)	4244.70	151.91
Milk heifer replacement (2007)	4152.90	150.96
Theil U statistic	0.026	
Steer Inventory =		
Intercept	4345.40	2065.20
(Calf crop – Calf Slaughter)$_{t-1}$	0.0140	0.0194
Steer Inventory$_{t-1}$	0.7307	0.1237
Steer Inventory (2006)	16464	485.94
Steer Inventory (2007)	16455	3540.20
Theil U statistic	0.037	
Other Heifer Inventory =		
Intercept	7328.90	1044.40
(Calf crop – Calf Slaughter)$_{t-1}$	-0.1229	0.0446
Hay price$_{t-1}$	29.847	9.9879
Cow cash return$_{t-1}$	-2.1421	1.901
Other heifer Inventory (2006)	9384.50	673.53
Other heifer Inventory (2007)	10045	699.49
Theil U statistic	0.032	
Bull Inventory =		
Intercept	417.53	146.79
All cow Inventory$_t$	0.0426	0.0032
Bull Inventory (2006)	2228.50	83.33
Bull Inventory (2007)	2251.20	83.094
Theil U statistic	0.016	
Heifers, Steers and Bulls (<500 lbs)=		
Intercept	24912	4763
(Calf crop – Calf Slaughter)$_{t-1}$	0.8651	0.2107
Hay price $_{t-1}$	-120.66	46.421
Heifers, Steers and Bulls (2006)	18259	3238.50
Heifers, Steers and Bulls (2007)	16032	3301.00
Theil U statistic	0.130	

Heifer Slaughter =		
Intercept	17738	2036
(Calf crop – Calf Slaughter)$_{t-1}$	-0.0685	0.0884
Milk Cow Inventory$_t$	0.4653	0.3108
Cow cash return$_t$	-3.6648	3.0474
Heifer Slaughter (2006)	11279	1039
Heifer Slaughter (2007)	10422	1084.50
Theil U statistic	0.104	
Steer Slaughter =		
Intercept	14992	3376.60
(Calf crop – Calf Slaughter)$_{t-1}$	-0.0089	0.0548
Feedlot costs/grass feeding cost	6.1466	9.1095
MA1 parameter (rho)	0.3922	0.17208
Steer Slaughter (2006)	16866	569.83
Steer Slaughter (2007)	16834	612.09
Theil U statistic	0.031	
Bull Slaughter =		
Intercept	226.11	38.339
(Cow Slaughter)$_t$	0.069	0.0059
Bull Slaughter (2006)	663.92	36.081
Bull Slaughter (2007)	632.45	36.248
Theil U statistic	0.228	
Beef Cow Slaughter =		
Intercept	-4047.90	2344.80
Beef Cow Inventory$_t$	0.3055	0.0651
Beef Heifer Replacement$_t$	-0.6913	0.2160
Cow cash return$_t$	-2.8133	1.9416
Hay price$_t$	11.069	9.2
Beef cow Slaughter (2006)	3663	533.50
Beef cow Slaughter (2007)	3312.80	793.23
Theil U statistic	0.159	
Milk Cow Slaughter =		
Intercept	-715.43	2246.30
Milk Cow Inventory$_t$	0.3379	0.1617
Milk Price$_t$	-6.7194	82.702
Milk Price$_{t-1}$	29.836	76.214
Milk cow Slaughter (2006)	2678.30	625.89

Milk cow Slaughter (2007)	2572.70	766.75
Theil U statistic	0.097	
Average beef dressed weight =		
Intercept	622.76	36.392
Cow slaughter$_t$	-0.013989	0.0042
Hay price$_t$	1.9161	0.2225
Average beef dressed weight (2006)	735.15	25.107
Average beef dressed weight (2007)	784.09	26.817
Theil U statistic	0.039	