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# FORECASTS OF FARM ANIMAL PRODUCTION IN THE NEW ENGLAND STATES AND IN THE U.S.

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**Abstract.** The purpose of the analysis is to forecast livestock and poultry numbers for New England and the U. S. The effect of increasing feed transportation rates on these numbers is also examined. The direct estimates of the reduced form equations are utilized in forecasting numbers for seven livestock and poultry classes. Forecast rules of thumb are specified in the simplified lag model. A large model consisting of 26 predetermined variables yields very high degrees of accuracy with errors mostly less than one percent.

## THE PROBLEM AND OBJECTIVES

Forecasting farm animal numbers has been a major concern of agricultural economists ever since the founding of the profession. This results in part from the fact that the livestock-feed sector is the largest single utilizer of agricultural production and marketing resources. Therefore, knowledge of livestock numbers has far reaching policy implications for producers, marketers and consumers.

New England livestock and poultry production depends heavily on feed grains supplied by the midwest. Importing nearly 100 percent of concentrate requirements means livestock producers are vulnerable to changes in feed grain prices and freight rates. Given the expected output prices, input factor prices, and current fixed resources, producers decide the number and weight of farm animals to produce. If the number of farm animals is known, the derived demand for feed to be purchased from the midwest can be estimated. Thus, knowledge about current and future animal numbers would be of interest to many decision makers, especially managers of mixing plants. Managers must plan for adequate supplies of feed ingredients and for sufficient storage well in advance of the ultimate utilization time. The main purpose of this paper is to forecast the number of farm animals in the New England states as well as the entire U.S. based on annual observations. A secondary purpose is to study the effect of increasing feed transportation rates on the number of farm animals in New England.

## APPROACHES

To forecast the number of farm animals, there are several approaches available. One approach is making use of time series analysis (Pindyck and Rubinfeld, and Nerlove, Grether and Carvalho) to identify the nature of livestock and poultry production cycles. In 1960, Harlow used the graphic method to identify four-year cycles in hogs. Abel in 1962 and Larson in 1964 proposed a harmonic model to explain the hog cycles. Jelavich in 1973 used a distributed lag technique for estimating harmonic motion in hog cycles. In 1975, Barksdale, Hilliard and Ahlund used harmonic analysis to estimate the lead-lag relationships among beef prices at different market levels and analyzed the timing relationship between price and quantity of beef at the slaughter level. In another approach extensive numbers of farm operating rules are established and livestock production is simulated with alternative policy decisions. Examples are the articles by Crom, and Crom and Maki. Still another method of attacking the forecasting problem is via a partial or complete supply-demand analysis of the livestock sector. Examples of the structural equation approach are the articles by Reutilinger, Maki, Hildreth and Jarett, Langemeier and Thompson, Hayenga and Hacklander, Myers, Havlicek and Henderson, Nelson and Spreen, and Arzac and Wilkinson.

Time series models provide a description of the random nature of the stochastic process that generated the sample of observations under study. The use of time series models depends upon sophisticated methods of extrapolation. Simulation models require very delicate definitions of operating rules and the results cannot be described with statistical confidence intervals. While the supply-demand approach is a standard econometric procedure, complications lie in the specification of the structural equations, the identification problem and the reconciliation of the discrepancy between *a priori* economic knowledge and the sign of parameter estimates.

In another approach the direct estimate of reduced form equations may be utilized in forecasting livestock numbers. This method of forecasting avoids the complexities involved both in the estimation of structural parameters and in the derivation of reduced form estimates from them. However, the reduced form direct estimates do not incorporate the *a priori* knowledge of structural specification and therefore will not make efficient forecasts if structural change occurs.[1] On the other hand, structural changes are difficult to numerically assess, and the value for the structural parameters would be difficult to modify. Besides, there are cases, such as recursive systems, in which the reduced form and structural equations may coincide.

In this paper, we start with a relatively large model using the direct reduced form approach in forecasting. With additional *a priori* knowledge the model is thus revised to drop the assumption of instantaneous interaction of demand and supply, and replaced by the one in which supply functions are determined by lagged variables. Concise models are then shown for easy forecast. Although the reduced-form approach does not require the specification of details of supply and demand functions, a set of predetermined variables in the system is conceived. Several alternatives are considered and their empirical results are reported. Included in this study are beef, milk cows, hogs, sheep, lambs, layers and broilers.

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[1]For an example of comparing the direct estimates of reduced form equations with the derived reduced form equations, see Egbert (Table 2).

**Table 1**
Summarizing Statistics for the Large Model with
26 Predetermined Variables, 1945-1975

| | New England | | | | | U.S. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Farm Animals | $R^2$ | $\overline{R}^{2}$ [a] | F [b] | CV [b] | Maximum Error | $R^2$ | $\overline{R}^{2}$ [a] | F [b] | CV [c] | Maximum Error |
| | | | | —Percent— | | | | | —Percent— | |
| Beef | 0.9967 | 0.9758 | 47.16 | 9.89 | 5.92 | 0.9999 | 0.9990 | 1197.88 | 1.08 | 1.10 |
| Milk Cows | 0.9995 | 0.9961 | 294.37 | 1.59 | 1.50 | 0.9999 | 0.9992 | 1530.87 | 0.97 | –0.94 |
| Hogs | 0.9969 | 0.9766 | 49.18 | 5.98 | –4.92 | 0.9429 | 0.5714 | 2.54 | 6.40 | –4.13 |
| Sheep | 0.9983 | 0.9874 | 91.37 | 2.82 | 2.20 | 0.9995 | 0.9959 | 282.18 | 2.13 | -1.15 |
| Lambs | 0.9987 | 0.9901 | 116.43 | 2.36 | 1.93 | 0.9975 | 0.9815 | 62.18 | 3.93 | –2.94 |
| Layers | 0.9759 | 0.8194 | 6.23 | 4.69 | 2.73 | 0.9980 | 0.9853 | 78.61 | 1.56 | -1.25 |
| Broilers | 0.9952 | 0.9639 | 31.81 | 6.94 | 4.50 | 0.9997 | 0.9974 | 446.80 | 2.78 | -1.33 |

[a]The adjusted $\overline{R}^2$ is obtained from the derived formula $\overline{R}^2 = R^2(1 - \frac{1}{F})$.

[b]The degrees of freedom are 26 and 4. The table values are approximately 5.76 at the 5 percent point and 13.88 at the 1 percent point.

[c]CV is calculated at the minimum standard error of forecast.

## A LARGE MODEL

If supply functions contain current prices and interact with demand functions,[2] the reduced form equations will be functions of all predetermined variables including those predetermined variables in demand functions, such as per capita income and population. Per capita income is considered the main demand shifter. Population is required in the aggregate demand function. On the supply side, it is hypothesized that the number of farm animals depends on the previous year's number, the current and lagged product prices, and lagged input price. The Chicago cash corn price is used to represent the input price. Hogs, sheep, lambs, layers and broilers have shorter life cycles, and the first price lagged effect is emphasized.[3] The effect of three years of lagged prices is emphasized for beef cows and milk cows since they have longer life cycles.

Thus, in the reduced form equations, the number of each of the farm animals is expressed as a function of all of the above mentioned predetermined variables. To summarize, they are: price of beef and price of milk (instead of milk cows) all lagged one, two and three years, one year lagged hog, sheep, lamb, egg, and broiler price, price of corn lagged one, two and three years, current per capita income, current population, and one year lagged number of each farm animal or poultry.[4] Since the New England states rely on feed grains shipped from the midwest, the freight rate from Toledo to Boston is also used in the New England forecasts. Freight rates are lagged one, two and three years.

Altogether, there are 26 predetermined variables. There are 14 jointly determined variables of number of animals and their current price. Since our only concern is with the number of animals, the price reduced form equations are not estimated. The seven quantity regressions are obtained based on 31 years (1945-1975) of annual observations.

Some summarizing statistics for the large model with 26 predetermined variables are listed in Table 1. The coefficients of determination $R^2$ are in general high. The adjusted $R^2$, indicated by $\overline{R}^2$, was calculated for each regression by adjusting degrees of freedom in variances. A surprising result is the $R^2$ value of 0.5714 for the forecast equation for U.S. hogs even though the forecast errors are small. The calculated F value for the hog equation is consistently low showing an insignificant result at the 5 percent level. The New England layers equation is significant at the 5 percent level and all other forecast equations are significant at the 1 percent level. The coefficients of variation are calculated by dividing the smallest standard error of forecast by the corresponding forecast and then multiplying by 100. Most of the coefficients are smaller for the U.S. than for New England. The largest variation relative to the mean is 9.89 percent for the New England beef equation while the forecast of the number of milk cows in the U.S. has a variation of less than 1 percent. The percentages of forecast error are calculated at the maximum deviation from the observation for each equation. The negative sign indicates the observation falls below the regression line.[5] In general, all equations have a good forecast ability, although the explanatory ability in terms of each variable is not consistently strong and for the U.S. hog equation there are more insignificant than significant variables. In order to improve the explanatory ability without losing much of the forecast ability, the following revisions are made.

## AN ALTERNATIVE MODEL

Instead of assuming that supply functions contain current prices, an alternative is to assume that supply functions do not respond to the current price of the own commodity and of other commodities, and are functions of lagged prices. This assumption is more realistic for agricultural products than for some industrial goods. Under such an assumption, supply functions interact with demand functions only recursively and not simultaneously. In other words, the predetermined variables in the demand function, such as per capita income and population, do not appear in the reduced form quantity function. With this specification, forecasting equations are estimated and some summarizing statistics are reported in Table 2.

[2]We have assumed that the supply of and demand for the livestock and poultry meat are measured in terms of the number of animals.

[3]The use of the lagged number of animals as an explanatory variable may be interpreted as a geometric distributed lag model (Judge, Griffiths, Hill and Lee, Chapter 16). An additional lagged price in the equation modifies the pattern of distributed lag effects.

[4]Prices are not deflated, hence factors of inflation are implicitly included in the regression equations.

[5]It appears that most maximum errors are positive for New England and negative for the U.S. This result is coincident since they do not appear in the same year.

**Table 2**
Summarizing Statistics for the Alternative Model with
24 Predetermined Variables, 1945-1975

| | New England | | | | | U.S. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Farm Animals | $R^2$ | $\overline{R}^2$ | F | CV[a] | Maximum Error | $R^2$ | $\overline{R}^2$ | F | CV | Maximum Error |
| | | | | —Percent— | | | | | —Percent— | |
| Beef | 0.9882 | 0.9411 | 20.96 | 16.16 | -13.30 | 0.9996 | 0.9979 | 584.56 | 1.69 | -1.82 |
| Milk Cows | 0.9994 | 0.9972 | 442.98 | 1.30 | 1.35 | 0.9999 | 0.9993 | 1890.72 | 0.86 | -1.12 |
| Hogs | 0.9939 | 0.9694 | 40.65 | 6.41 | 6.10 | 0.9294 | 0.6469 | 3.29 | 5.39 | 3.99 |
| Sheep | 0.9971 | 0.9883 | 87.40 | 2.92 | 3.10 | 0.9994 | 0.9970 | 422.62 | 1.67 | -1.19 |
| Lambs | 0.9961 | 0.9803 | 63.08 | 3.27 | 2.62 | 0.9964 | 0.9821 | 69.43 | 3.58 | -3.23 |
| Layers | 0.9706 | 0.8531 | 8.26 | 4.11 | -2.51 | 0.9755 | 0.8774 | 9.95 | 4.46 | -3.62 |
| Broilers | 0.9900 | 0.9501 | 24.79 | 8.05 | 7.10 | 0.9984 | 0.9919 | 154.21 | 5.08 | -28.29[b] |

[a]CV is calculated at the minimum standard error of forecast.
[b]The next two largest errors are 19.22 percent and -6.25 percent.

The size of the coefficient of variation and percentage of maximum errors are reduced for the milk cows and layers in New England as compared with the larger model. For all other equations the errors and the CV values have increased.

For the U.S. a comparison of this model with the previous one leads to mixed results. For beef, layers and broilers, the alternative model increased both the coefficients of variation and percentage of maximum error. The broiler equation failed to forecast the extreme values and resulted in a maximum forecast error of -28.29 percent. For milk cows, sheep, and lambs, the coefficient of variation was reduced while the percentage of maximum error was increased. The alternative model clearly improved the hog forecasts.

In this model, the reduced form equations and the structural equations coincide. However, the parameter estimates are not consistently significant. This is primarily caused by too many explanatory variables confined in a linear approximation of behavioral equations. In econometric terminology, it is quite likely caused by multicollinearity and misspecification. A natural revision of the equations is to incorporate *a priori* knowledge of the structural equations to reduce the number of variables.

## SIMPLIFIED LAG MODELS

If the two-year and three-year lagged variables, which yield insignificant parameter estimates in the previous model, are deleted, the reduced form supply equations can be hypothesized as functions of the lagged own price, the lagged corn price and the lagged own quantity.[6]

Table 3 shows the regression results for U.S. farm animals. The numbers are in thousands of head for beef, layers and broilers, and in hundreds of head for milk cows, hogs, sheep and lambs. The prices are cents per hundredweight for beef, cents per one-hundred pounds for milk, hogs, sheep, and lambs, cents per dozen for eggs, cents per pound for broilers, cents per bushel for corn and for corn plus lagged freight rate. The signs are consistent with economic theory and most of the parameter estimates are significant at the 1 percent level. The lagged own price is more significant for livestock than for poultry. The lagged own quantity is very significant in general.[7]

For New England, the results are quite similar to the U.S. except that the effect of lagged corn price is insignificant. This may be due to the fact that the Chicago cash corn price does not represent the input cost for New England. Therefore the freight rate from Toledo to Boston is added to the Chicago corn price. The results are given in Table 4.

Adding the freight rate still does not render the corn price a significant variable in explaining livestock numbers although the standard errors of the estimates are somewhat reduced. The large standard errors of the regression coefficients relative to the parameter estimates result in small t values ranging from 0.08 to 0.9 in absolute values. The lagged own price has the right positive sign and is significant at the 1.0 percent level for broilers. The own lagged quantity is significant at the 1.0 percent level for all classes of animals. The high F value for all equations shows the significant influence the lagged variables have on animal numbers.

One problem remaining is that four out of seven coefficients for the lagged own quantity are greater than unity and thus cannot be interpreted as a distributed lag model.[8] For the lagged effects to be diminishing, the lagged coefficients must be less than unity. This leads to restricting the lagged coefficients to be less than unity in estimation. Before the restricted least squares is employed, compatibility tests (Theil) are performed for those coefficients that are greater than unity. In other words, we test to see if the sample information and the *a priori* knowledge are compatible. In particular, the lagged coefficients are tested to see if they are significantly different from 0.9999. The results show that they are not significantly different at the 95 percent confidence level. The restricted least squares results are reported in Table 5.

The restricted least squares results are very close to the conventional least squares results. The differences are due to the small adjustment of the lagged coefficients. These final results show that the lag effects are diminishing very slowly. An exception is the U.S. hog production. The lagged coefficient is 0.3752 (Table 3) and

[6]A test of zero restrictions on the parameters of the omitted variables could be performed (by an F test) as a package deal instead of the individual t tests. Fortunately the F test is not necessary in this case since the individual t tests on the omitted variables are all significant at the 5 percent level. For the use of prior information in estimating the parameters of economic relationships, see the article by Judge and Yancey.

[7]For beef cows, the coefficient of the lagged own quantity 0.9862 is quite close to the estimate 0.9758 obtained by Arzac and Wilkinson (Table 2, equation 10).

[8]For alternative distributed lag models, see Part VI of the book by Judge, Griffiths, Hill and Lee.

**Table 3**
Regression Results for a Three Independent Variable Model for U.S. Farm Animals, 1945-1975

| | Constant Term | Lagged Own Price | Lagged Corn Price | Lagged Own Quantity | $R^2$ | $\overline{R^2}$ | F |
|---|---|---|---|---|---|---|---|
| Beef | -573.35 | 1.0081 | -0.2197 | 0.9862 | 0.9935 | 0.9928 | 1367.78 |
| | | (0.3283)** | (0.3878) | (0.0226)** | | | |
| Milk Cows | -3054.20 | 4.6701 | -0.4842 | 1.0600 | 0.9969 | 0.9966 | 2872.94 |
| | | (1.3004)** | (0.2112)* | (0.0234)** | | | |
| Hogs | 60251.63 | 9.4525 | -16.6973 | 0.3752 | 0.5579 | 0.5088 | 11.36 |
| | | (2.7784)** | (3.4775)** | (0.1519)* | | | |
| Sheep | 2361.97 | 2.5049 | -1.7709 | 0.8986 | 0.9706 | 0.9673 | 297.19 |
| | | (1.2616)* | (0.7250)* | (0.0321)** | | | |
| Lambs | -3186.74 | 1.4845 | -1.2892 | 1.0583 | 0.9617 | 0.9574 | 225.73 |
| | | (0.7583) | (0.5343)* | (0.0830)** | | | |
| Layers | 90229.21 | 1063.7730 | -20.0146 | 0.7362 | 0.8574 | 0.8416 | 54.13 |
| | | (702.4619) | (9.7906)* | (0.0582)** | | | |
| Broilers | 200346.1 | 939.5521 | -91.8117 | 0.9951 | 0.9933 | 0.9926 | 1337.75 |
| | | (6648.155) | (57.0010) | (0.0453)** | | | |

Note: The numbers in the parentheses are the standard errors of the regression co-efficient. The F table value is 4.6 at the 1 percent level for the degrees of freedom 3 and 27 and * is significant at the 5 percent level and ** at the 1 percent level in this table and Table 4.

**Table 4**
Regression Results for a Revised Three Independent Variable Model for New England Farm Animals, 1945-1975

| | Constant Term | Lagged Own Price | Lagged Corn Price Plus Lagged Freight Rate | Lagged Own Quantity | $R^2$ | $\overline{R^2}$ | F |
|---|---|---|---|---|---|---|---|
| Beef | -0.93 | 0.0230 | -0.0117 | 1.0183 | 0.9390 | 0.9322 | 138.45 |
| | | (0.0129) | (0.0131) | (0.0744)** | | | |
| Milk Cows | -927.17 | 0.7716 | 0.1505 | 1.0592 | 0.9895 | 0.9883 | 851.60 |
| | | (0.4919) | (0.6960) | (0.0370)** | | | |
| Hogs | -99.57 | 0.0978 | -0.3148 | 0.9523 | 0.9570 | 0.9522 | 200.12 |
| | | (0.1014) | (0.9650) | (0.0464)** | | | |
| Sheep | -47.72 | 0.7488 | -0.1512 | 0.9940 | 0.9160 | 0.9067 | 98.09 |
| | | (0.4766) | (0.2586) | (0.0685)** | | | |
| Lambs | -86.91 | 0.3474 | -0.1426 | 1.0715 | 0.8952 | 0.8836 | 76.90 |
| | | (0.1679)* | (0.1643) | (0.0908)** | | | |
| Layers | 566.27 | 28.7496 | -0.5261 | 0.8881 | 0.6163 | 0.5737 | 14.46 |
| | | (37.5207) | (6.3423) | (0.2027)** | | | |
| Broilers | -20110.68 | 908.483 | -14.2907 | 1.0635 | 0.9658 | 0.9620 | 254.0 |
| | | (277.704)** | (20.4437) | (0.0591)** | | | |

its mean lag is 0.6 years (0.3752/(1-0.3752)). Most of the number of farm animals in New England tend to be the same as that of the previous year, with the exception of a 12 percent reduction for layers and a 5 percent reduction for hogs (Table 4).

## CONCLUDING REMARKS

In forecasting the number of farm animals, the reduced form approach seems to be satisfactory. The large size model works very well in terms of the small percentage of maximum forecast error. The minimax percentage error is less than 1.0 percent for U.S. milk cows and the maximax percentage error is less than 6.0 percent for New England beef. The coefficients of variation for forecasts follow a similar pattern of the percentage of maximum errors. It ranges from less than 1.0 percent for U.S. milk cows to 10.0 percent for New England beef. The large model is also capable of forecasting many extreme values of past observations. This phenomenon is detected when a condensed model fails to forecast some extreme values.

**Table 5**
Restricted Least Squares Results for Selected Farm Animals, 1945-1975

| | Constant Term | Lagged Own Price | Lagged Corn Price | Lagged Corn Price Plus Freight Rate | Lagged Own Quantity |
|---|---|---|---|---|---|
| | | | | | (Restricted) |
| *United States* | | | | | |
| Milk Cows | -1136.11 | 1.7042 | -0.0887 | — | 0.9999 |
| | | (0.6501)* | (0.1579) | | |
| Lambs | -1339.41 | 1.0128 | -1.0936 | — | 0.9999 |
| | | (0.3516)** | (0.4522)* | | |
| *New England* | | | | | |
| Beef | -0.96 | 0.0247 | — | -0.0109 | 0.9999 |
| | | (0.0109)* | — | (0.0124) | |
| Milk Cows | -302.40 | 0.1158 | — | 0.6932 | 0.9999 |
| | | (0.2810) | | (0.6231) | |
| Lambs | -39.53 | 0.2654 | — | -0.1384 | 0.9999 |
| | | (0.1310)* | | (0.1631) | |
| Broilers | -10274.37 | 664.0818 | — | -12.8970 | 0.9999 |
| | | (159.8283)** | | (20.4590) | |

The first revised model is based on the assumption of recursive interaction between demand and supply. This reduces the number of predetermined variables for the quantity equations. For New England the percentage of maximum error is reduced for milk cows and layers but increases for all other classes of animals. The percentage of maximum error is reduced for U.S. hogs, but increases slightly for all other classes except the U.S. broiler equation, which fails to forecast two extreme values.

The shortcoming of the large model in forecasting is the large scale computation required for 26 predetermined variables and their parameter estimates. Fortunately, most of the variables are lagged values of the known variables. The only current variables are per capita income and population. These two variables should be projected for the future year to forecast future numbers of farm animals.

In seeking economic explanation in addition to the forecast, some concise models were constructed. For the U.S. farm animals, lagged own price, lagged corn price and lagged own quantity are used as explanatory variables. The lagged own quantity is the most significant variable in determining the current number of farm animals. The relatively small coefficient of lagged own quantity for the U.S. hog equation indicates the magnitude of fluctuation of hog production. U.S. broiler and beef production seem to follow the previous year's production with only minor adjustment in response to lagged own price and lagged corn price.

For New England, the lagged own price is significant only for broilers, lambs, and beef (Table 5). Similar to the U.S. results, lagged own quantity explains the current number of animals better than other variables. However, probably not much emphasis should be placed upon any of the New England results for beef, hogs, sheep and lambs. It is quite likely that the small New England firms producing these classes of livestock do not respond in a similar manner to the same economic stimuli as do large commercial dairy and poultry farms.

The concise models give reasonably good forecasts although goodness-of-fit is sacrificed as evidenced by the reduced value of the coefficient of determination. However, the reductions are small for all classes except for the New England layers. The $R^2$'s are lower by 3 percent to 10 percent as compared with the large model.

For actual future forecasting, models should be constantly revised by updating the input data and by adding new information. In updating, perhaps, the wage rate and interest rate should be added as additional explanatory variables.

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