# Demand for Feed Grains and Concentrates by Livestock Category

## James W. Richardson and Daryll E. Ray

Livestock feed demand is a collection of derived feed demands by various livestock categories. A structural understanding of demand for feed grains and total concentrates requires knowledge of separate feed demand relationships for each major livestock category. While a number of aggregate livestock feed demand relationships have been estimated, little is known about the structure of feed demand by livestock type. In this study unique livestock feed demand relationships for feed grains and total concentrates are estimated for each of seven major livestock categories. The estimated relationships show substantial differences in elasticities of concentrate and feed grain feed demand with respect to feed prices and with respect to livestock price across livestock groups. Using feed demand parameters by livestock category enables analysts to evaluate policy effects of changes in feed demand quantities and feed costs within the livestock economy, as well as to provide more reliable estimates of the total change in feed demand.

The demand for feed grains and other feed concentrates is a collection of demands by various livestock categories.[1] Since ration flexibility varies considerably by type of livestock, the elasticities or other economic parameters for the separate feed demand relationships are likely to differ markedly across livestock categories. More information is needed about the structure of demand for feed grains and feed concentrates by type of livestock. Knowledge of feed demand parameters by livestock category would increase structural understanding of the underlying determinants of aggregate livestock demand for feed grains and concentrates. Also, this knowledge would expand the analytical base for policy and other economic analyses that span the crop and livestock sectors.

James W. Richardson and Daryll E. Ray are Assistant Professor, Texas A&M University and Associate Professor, Oklahoma State University, respectively. Comments by M. C. Hallberg, Luther Tweeten, James Trapp and James Plaxico at various stages of this research were very much appreciated. Comments by the editor and three anonymous reviewers have improved the presentation.

[1]For this study feed grains include wheat, corn, rye, grain sorghum, barley and oats. Total concentrates fed to livestock are comprised of feed grains fed and by-

A number of studies have estimated aggregate livestock feed demand relationships for feed grain [Ahalt and Egbert; Brandow; Feltner; Fox and Tauelber; and Mielke]. Total livestock demand for feed grains is generally postulated as a function of feed grain prices, an index of livestock prices, an aggregate measure of livestock numbers, and in some cases, the price of high protein feed [Butell and Womack; and Chuang]. Other studies have reported separate feed demand equations for corn, grain sorghum, barley, oats and by-product feeds [King; Meinken; and Womack]. Womack describes the derived nature of livestock feed demand, and draws upon the derived demand concept in specifying aggregate livestock feed demand relationships. Despite interest in livestock feed demand over the past decade, no studies have estimated feed demand relationships by livestock category.

The objective of this study is to estimate direct and cross price elasticities of demand

product feeds fed. By-product feeds and high protein feeds are comprised of oilseed meals, animal protein feeds, grain protein feeds and other by-product feed. Data for these series are reported in Table 91 of the Livestock-Feed Relationships Bulletin [USDA, 1975]. Values for corn fed to livestock were adjusted for the quantity of corn silage included in the series.

for feed grains and total concentrates for each of seven major livestock categories. Following sections describe the model, estimation procedures, results, study limitations, and conclusions.

## Model Framework

Feed demand relationships for concentrates and feed grains are developed for each of seven major livestock categories: cattle and calves, hogs, sheep, broilers, turkeys, egg production and milk production. The demand for concentrates by each livestock group is equal to the level of livestock production multiplied by the average concentrates feed conversion rate.

(1)  Demand for  $\equiv$
     Concentrates$_{it}$

Livestock          Average Concentrate
Production$_{it}$  *  Feed Conversion Rate$_{it}$

where: t is the current year and i specifies the livestock category. Livestock production in the current year is largely determined by supply decisions made in previous periods. In livestock feed demand research, current year aggregate livestock production can be considered fixed.[2] In a recent study, Womack considers annual livestock population as fixed with years due to the length of time required in the reproductive process for cattle, sheep and hogs, and the fact that poultry makes up only 12 percent of the total livestock population. The concentrate feed conversion rate for each livestock category is expected to be inversely related to the price of concentrate feeds and positively related to the price of the livestock category. The average concentrate feeds conversion rate for the ith livestock category is hypothesized to be a function of corn price, the relevant livestock price, a time trend and an error term.

(2)  Average Concentrate       $=$
     Feed Conversion Rate$_{it}$

     $f_i$ (corn price$_t$, livestock price$_{it}$,
          time, $e_{it}$)

A single equation for the quantity of concentrates demanded by each livestock category could be postulated. Each relationship would contain the respective livestock production variable as well as the explanatory variables specified in equation (2). However, by using the two equations, the elasticity of concentrate demand for the ith livestock category with respect to production is constrained to its true value, unity. A unitary elasticity implies that a given percentage change in livestock output should result in the same percentage change in concentrates demanded — everything else, including prices and feeding efficiency, held constant.

The demand for feed grains as a livestock feed is estimated within the context of the more general demand for total concentrates. The mix of specific feed types in total concentrate feed depends, in a large part, on the relative prices of feed grains and high protein feeds. The demand for feed grains by the ith livestock category can be specified as a product of the demand for total concentrates by the ith livestock category and the estimated percent of feed grains in concentrates fed to the ith livestock category (3).

(3)  Demand for           $\equiv$
     Feed Grains Fed$_{it}$

     Total Concentrates
     Demanded$_{it}$        *

          Percent of Feed Grains
          in Concentrates Fed$_{it}$

---

[2]This research focuses only on livestock feed demand portion of the livestock-feed economy. These livestock feed demand relationships could be linked to supply and demand relationships for crops and livestock and solved simultaneously in a complete livestock-feed model. In such a model, feed prices, livestock production levels and livestock prices would be endogenous to the model rather than exogenous as they are in this study.

Total concentrates demanded by the $i^{th}$ livestock category come from equation (1). The percent of feed grains in concentrates demanded by the $i^{th}$ livestock type is hypothesized to be a function of feed grain prices, by-product feed prices, the relevant livestock price, a time trend, and an error term.

(4)   Percent Feed
       Grains in Total       =
       Concentrates Fed$_{it}$

   $g_i$ (feed grain price$_t$, livestock price$_{it}$, price of by-product$_t$, time, $u_{it}$)

Negative coefficient signs are expected for feed grains and livestock prices and a positive sign is postulated for the price of by-product feeds. The sign on the trend variable may be either positive or negative, depending upon changes in nutrition recommendations for the livestock category.[3] Using equations (3) and (4) to estimate demand for feed grains fed to each category constrains the elasticity of demand with respect to production of the livestock category to its true value, unity.

Total livestock feed demand for total concentrates and feed grains is estimated as the sum of the quantities demanded by each of the seven livestock categories (cattle and calves, hogs, sheep, broilers, turkeys, eggs, and milk) plus a residual quantity fed to other livestock. The quantity of total concentrates and feed grains fed to other livestock is estimated with equations provided in Appendix A. The major advantage of estimating feed demand for the various livestock types via equations (1) through (4) is that feed demand responds to changes in the mix of livestock produced, as well as to short run adjustments

in the feed ration in response to changes in the relative price of feed and prices received for individual livestock categories. This relation is of particular importance in tracing the impacts of federal price support programs for crops on the current and future demand for livestock feeds. If crop prices are affected by a change in farm policy, the feed demand equations allow varying response in ration adjustment by livestock category and utilize estimated impacts on the future composition of livestock production to estimate the net effect on total feed demand. In aggregate feed demand equations, an average response to the feed price change is estimated over all livestock. This response is based on the composition of livestock production during the time period used to estimate the equations. The mix of livestock types may differ substantially for the years included in the analysis.[4]

## Model Estimation

Equations (2) and (4) are estimated for each of the seven major livestock categories. Published data on the annual quantities of feed grains and total concentrates fed to each livestock category are published by the USDA [USDA, 1975]. Historical feed conversion rates for each livestock category in equation (2) are calculated by dividing total concentrates fed to each category by the respective pounds of live-weight production [USDA, 1976; USDA, 1975].[5] Historical values for the percent of feed grains in total concentrates fed for each livestock category used in equation (4) are obtained by dividing the quantity of feed grains fed to each category by the quantity of total concentrates fed to the respective category. Corn and soybean meal are used as measures of feed grain and by-product feed prices, respectively. The price series for corn, soybean meal, and the live-

---

[3]Other explanatory variables were tried in equations (2) and (4). The additional explanatory variables tended to be category specific such as: animal units$_{it}$, hay price$_t$, number of dairy cows on farms, etc. Hay price was rejected in the beef, sheep, and milk equations due to low "t" values. The animal units variable was rejected in all but one equation because it resulted in lower F ratios and larger standard errors for the dependent variables.

[4]Equations estimated by livestock category also contain average responses over the estimation period, but they do allow varying production levels by livestock category.

[5]All feeds are measured in terms of million of tons of corn equivalent feed units.

stock categories are annual average prices [USDA, 1976]. A least squares regression procedure is used to estimate all equation parameters.[6] Several functional forms were tested and only those producing the correct signs on own livestock price, corn price and soybean meal price were retained. The equations reported for the study were selected on the basis of F tests, standard error of the equation, and the coefficient of determination.

Explanatory variables other than those initially postulated were tried in several different functional forms. Hay price was tried as a proxy for roughage feed costs in the cattle and calves and dairy production equations; however, hay price was rejected due to low "t" values. Individual grain consuming animal units were tried and rejected in all equations except the broiler feed conversion ration equation, where it decreased the standard error from 0.25 to 0.18.

Empirical results for the feed conversion equation (2) are presented in Table 1 for the seven livestock categories identified as C1 through C7. Table 2 contains the empirical results for the percent of feed grains in concentrates fed to livestock, equation (4), with livestock categories P1 though P7. The student "t" values and elasticities computed at the mean are reported below their respective regression coefficients for the fourteen equations reported in Tables 1 and 2. The F ratio, the coefficient of variation, the standard error of the dependent variable, and the Durbin-Watson D statistic are reported for each of the equations.

The estimated equations and identities in Tables 1 and 2 and Appendix A were modeled in a computer program to simulate estimates of livestock feed demand for total concentrates and feed grains. Root mean square and Theil U2 statistics for comparing simulated and actual values of livestock feed demand by category over the observation

period are reported in Table 3.[7] Based on the test statistics reported in Table 3, the model appears to be a good predictor of livestock feed demand for feed grains and total concentrates by livestock category and in aggregate.

## Elasticities of Concentrate and Feed Grain Demand

*A priori* we would expect price elasticities of demand for total concentrates fed to be more inelastic than elasticities of demand for feed grains fed because concentrate feeds, taken together, have fewer substitutes than any one type of concentrate. Table 4 summarizes the elasticities of feed demand for total concentrates and feed grains with respect to the price of corn and the price of each of the seven livestock categories. The elasticities of demand for total concentrates fed come directly from Table 1. Elasticities of demand for feed grains are computed as the sum of the corresponding price elasticities for the feed conversion rate (Table 1) and for the percent of feed grains in concentrates (Table 2).[8] Elasticities for aggregate feed demand are based on the results of simulating the computer model with a 10 percent increase

---

[7]Root Mean Square percent error =

$$\frac{1}{T} \sqrt{\Sigma \left( \frac{P_t - A_t}{A_t} \right)^2} \times 100.0$$

$$\text{Theil U2} = \frac{\sqrt{\Sigma (P_t - A_t)^2}}{\sqrt{\Sigma (A_t)^2}}$$

The Root Mean Square Error, expressed as a percent, is a measure of the deviations of the predicted value from the actual. The closer to zero is the value of this statistic, the better the model predicts the particular variable. The Theil Inequality Coefficient (U2) measures the ability of a simulation model to give retrospective predictions of the observed data [Theil]. According to Leuthold, the Theil U2 statistic has a lower bound of zero when the model is a perfect predictor and a value of one when the model is a no-change extrapolation.

[8]Since substituting equation (1) into equation (3) yields a multiplicative feed grain demand equation, the usual procedure for determining elasticities from multiplicative equations applies [Allen, p. 252]. For example, the elasticity of feed grain feed demand for hogs with respect to corn price is −.051 (from Table 1) plus −.092 (from Table 2) or −.143.

---

[6]A simultaneous estimation procedure could be used to re-estimate the equations when the feed demand relationships are linked to a complete model of the livestock and feed economies.

**TABLE 1.** Regression Equations for Feed Conversion Rates for Each of the Seven Major Livestock Categories, 1960-1974.[a]

| | | | | | | |
|---|---|---|---|---|---|---|
| C1. Cattle | | $-162.0067 + 5.9794\,OLP_t - 1.0348\,CP_t + 0.0831\,T$ | | | | |
| and | t | 5.290 | 11.403 | 6.138 | | |
| Calves | e | (0.894) | (−0.834) | | | |
| | | F = 81.2 | $R^2$ = .96 | S.E. = 0.113 | D = 2.16 | $\bar{Y}$ = 1.713 |
| C2. Hogs[b] | | $4.9448 + 3.3162\,OLP_t - 0.1959\,CP_t$ | | $\rho = 0.6227$ | | |
| | t | 1.700 | 0.800 | | 3.032 | |
| | e | (0.132) | (−0.051) | | | |
| | | F = 3.80 | $R^2$ = .53 | S.E. = 0.044 | D = 1.84 | $\bar{Y}$ = 5.446 |
| C3. Sheep | | $1.1778 + 4.4653\,OLP_t - 0.2883\,CP_t$ | | | | |
| and | t | 6.334 | 3.500 | | | |
| Lambs | e | (0.566) | (−0.222) | | | |
| | | F = 26.59 | $R^2$ = .82 | S.E. = 0.096 | D = 1.20 | $\bar{Y}$ = 1.796 |
| C4. Broilers | | $2.4216 - 0.0587\,(CP_t \div OLP_t) + 0.5316\,CAU_t$ | | | | |
| | t | 1.980 | 0.709 | | | |
| | e | (−0.180)[c] | | | | |
| | | F = 4.39 | $R^2$ = .42 | S.E. = 0.181 | D = 0.99 | $\bar{Y}$ = 2.806 |
| C5. $\ell$Turkeys | | $16.5376 + 0.1967\,\ell OLP_t - 0.0689\,\ell CP_t + 0.0797\,T$ | | | | |
| | t | 2.264 | 1.222 | 6.34 | | |
| | e | (0.197) | (−0.069) | | | |
| | | F = 29.50 | $R^2$ = .89 | S.E. = 0.014 | D = 1.71 | $\bar{Y}$ = 5.216 |
| C6. Egg Prod. | | $-76.7722 + 2.6349\,OLP_t - 0.5622\,CP_t + 0.0769\,MP_t + 0.0419\,T$ | | | | |
| | t | 2.670 | 3.300 | 1.990 | 2.770 | |
| | e | (0.153) | (−0.122) | (0.069) | | |
| | | F = 16.88 | $R^2$ = .87 | S.E. = 0.114 | D = 1.44 | $\bar{Y}$ = 6.384 |
| C7. Milk Prod.[b] | | $0.4650 - 0.00129\,(CP_t \div OLP_t)$ | | $\rho = 0.7144$ | | |
| | t | 1.677 | | 5.003 | | |
| | e | (−0.080)[c] | | | | |
| | | F = 15.00 | $R^2$ = .73 | S.E. = 0.0001 | D = 1.95 | $\bar{Y}$ = 0.4162 |

[a] The "t" values for the regression coefficients are presented below their respective regression coefficients. Elasticities calculated at the mean are presented in parentheses below the "t" values. Other statistics for each regression are: the F ratio, the coefficient of determination ($R^2$), estimate of the equation standard (S.E.), the Durbin-Watson D statistic, and the mean of the dependent variable ($\bar{Y}$). Feed conversion rates are pounds of feed per pound of liveweight production except for eggs and milk which are per dozen and per pound of milk equivalents, respectively; $OLP_t$ — own livestock price received by farmers, dollars per pound or unit of production; $CP_t$ — average corn price received by farmers, $/bu.; T — time in years, 1960, 1961, . . . , 1974; $CAU_t$ — chicken grain consuming animal units, in millions; $MP_t$ — soybean meal price, $/cwt. Any variable name prefixed with "$\ell$" implies $\log_{10}$ for the particular variable.

[b] Estimated using a first order autoregressive structure for the residuals, the $\rho$ value reported is the estimate of the first order autocorrelation coefficient.

[c] The elasticity as reported is with respect to corn price. Since the independent variable is a ratio, the elasticity with respect to own livestock price is the reported elasticity but with the sign reversed [Ahalt and Egbert, p. 46].

in corn prices, a 10 percent increase in livestock production, and a 10 percent increase in the price of the livestock categories. The aggregate elasticities are then computed using the observed changed in feed grain feed demand and total concentrates demand.

Elasticity levels vary considerably among livestock categories. For example, the own price elasticity of the demand for feed grains in milk production is extremely inelastic at −.15, while for cattle and calves the respective elasticity is −.94. Cross elasticities of demand for feed grains with respect to live-

stock price range from about .89 for cattle and calves to .04 for hogs. The differing elasticities reflect varying degrees of flexibility in ration composition by livestock category. Elasticities are higher for cattle and calves than for hogs and poultry since roughages can readily be substituted in the production of cattle and calves but few substitutes are available in hog and poultry production.

The estimate of the overall elasticity of demand for feed grains fed to all livestock with respect to corn price is −0.28, which is in line with the −0.22 to −0.23 values re-

TABLE 2.  Regression Equations for Percent of Feed Grains in Concentrates for Each of the Seven Major Livestock Categories, 1960-1974.[a]

| | | | | | | |
|---|---|---|---|---|---|---|
| P1. Cattle | $-2135.0543 - 6.9267\ CP_t + 1.2764\ MP_t + 1.2764\ T$ | | | | | |
| and | t | 3.315 | 1.816 | 4.105 | | |
| Calves | e | (−.114) | (0.087) | | | |
| | | F = 33.35 | $R^2$ = .90 | S.E. = 2.08 | D = 1.12 | $\bar{Y}$ = 83.41 |
| P2. Hogs | $91.4014 - 38.3473\ OLP_t - 5.4189\ CP_t + 1.0120\ MP_t$ | | | | | |
| | t | 1.792 | 3.576 | 2.110 | | |
| | e | (−.099) | (−.092) | (.071) | | |
| | | F = 27.70 | $R^2$ = .88 | S.E. = 1.38 | D = 1.84 | $\bar{Y}$ = 81.54 |
| P3. $\ell$Sheep and | $20.1642 - 0.2307\ \ell OLP_t - 0.0096\ \ell CP_t + 0.2206\ \ell MP_t - 0.0095\ T$ | | | | | |
| Lambs | t | .797 | .109 | 1.697 | 1.389 | |
| | e | (−.230) | (−.009) | (0.220) | | |
| | | F = 9.82 | $R^2$ = .79 | S.E. = 2.00 | D = 1.07 | $\bar{Y}$ = 50.05 |
| P4. Broilers | $-535.4735 - 48.1269\ OLP_t - 0.6324\ CP_t + 0.3713\ MP_t + 0.3041\ T$ | | | | | |
| | t | 1.034 | 0.233 | 0.476 | 0.887 | |
| | e | (−.133) | (−.002) | (.037) | | |
| | | F = 2.71 | $R^2$ = .52 | S.E. = 2.04 | D = 1.23 | $\bar{Y}$ = 56.46 |
| P5. Turkeys | $2127.5803 - 26.2702\ OLP_t - 4.5679\ CP_t + 1.3004\ MP_t - 1.0467\ T$ | | | | | |
| | t | 1.017 | 1.917 | 1.381 | 2.923 | |
| | e | (−.097) | (−.099) | (.118) | | |
| | | F = 12.80 | $R^2$ = .84 | S.E. = 2.32 | D = 1.13 | $\bar{Y}$ = 63.57 |
| P6. $\ell$Egg | $-5.0535 - 0.0071\ \ell OLP_t - 0.1062\ \ell CP_t + 0.0035\ T$ | | | | | |
| Prod. | t | .108 | 2.521 | 4.160 | | |
| | e | (−.007) | (−.106) | | | |
| | | F = 7.62 | $R^2$ = .70 | S.E. = 1.28 | D = 1.98 | $\bar{Y}$ = 66.976 |
| P7. $\ell$Milk | $1.8375 - 0.0048\ \ell OLP_t - 0.0786\ \ell CP_t + 0.0415\ \ell MP_t$ | | | | | |
| Prod. | t | .108 | 1.582 | 1.529 | | |
| | e | (−.005) | (−.078) | (0.042) | | |
| | | F = 2.30 | $R^2$ = .46 | S.E. = 3.00 | D = 1.58 | $\bar{Y}$ = 74.24 |

[a] The student "t" values for the regression coefficients are presented below their respective regression coefficients. Elasticities calculated at the mean, are presented in parentheses below the student "t" values. Other statistics for each regression are: the F ratio, the coefficient of determination ($R^2$), estimate of the equations standard (S.E.), the Durbin-Watson D statistic, and the mean of the dependent variable ($\bar{Y}$). Independent variable definitions are given in Table 1 footnote a.

ported by Ahalt and Egbert. The elasticity of demand for feed grains fed to all livestock with respect to livestock prices is 0.22 about the same as the value 0.21 reported by Ahalt and Egbert. The elasticity of demand for feed grains fed to all livestock with respect to livestock production is 1.0, which is the true value.

**Study Limitations**

Among the limitations of the study are the use of single equation estimation techniques and the unknown extent of error in the feed consumption data. The equation parameters were estimated with ordinary least squares regression although the feed demand relationships are actually part of a larger simultaneous system. The data on quantities of feed

grains and all concentrates fed to specific livestock categories are probably subject to more error than the respective aggregate series. The use of annual livestock production and feed demand data is also a limitation since the quantity of livestock production can and does change within the year, as a result of changes in feed rations and length of time on feed. Data for feed demand by livestock category are presently only available from the USDA on an annual basis.

**Summary and Conclusions**

Since livestock demands for feed grains and total concentrates are the sum of the respective derived feed demands by category of livestock, it is logical to model feed demand relationships by livestock category. Such a

**TABLE 3.  Validation Statistics for the Feed Demand Model, 1961-1974.**

|  | Mean of Actual Observations (m.t.) | Root-Mean Square Percent Error (%) | Theil Inequality Coefficient (U2) |
|---|---|---|---|
| **Feed Demand for Feed Grains by:** | | | |
| Cattle & Calves | 26.79 | 1.548 | 0.050 |
| Hogs | 43.20 | 1.717 | 0.060 |
| Sheep & Lambs | 0.54 | 2.100 | 0.064 |
| Broilers | 7.46 | 1.94 | 0.069 |
| Turkeys | 3.41 | 2.511 | 0.097 |
| Eggs | 12.02 | 0.715 | 0.027 |
| Milk | 18.66 | 1.198 | 0.045 |
| **Feed Demand for Total Concentrates by:** | | | |
| Cattle & Calves | 31.40 | 1.800 | 0.055 |
| Hogs | 53.07 | 1.473 | 0.053 |
| Sheep & Lambs | 1.09 | 1.708 | 0.056 |
| Broilers | 13.13 | 1.974 | 0.071 |
| Turkeys | 5.39 | 2.104 | 0.078 |
| Eggs | 17.87 | 0.553 | 0.020 |
| Milk | 25.10 | 0.553 | 0.020 |
| **Total Feed Demand for Feed Grains**[a] | 136.526 | 0.646 | 0.022 |
| **Total Feed Demand for Total Concentrates**[a] | 180.616 | 0.561 | 0.019 |

[a] Total livestock feed demand is the sum of feed demands for the seven livestock categories and demand by other livestock categories (see Appendix A).

model allows a more complete analysis of federal crop and livestock policies on the demand for feed and on changes in per unit feed costs. While a number of aggregate livestock feed demand relationships have been estimated, little is known about the structure of feed demand by livestock type. In this study livestock feed demand relationships for feed grains and total concentrates are estimated for each of seven major livestock categories.

The estimated relationships show substantial differences in elasticities of concentrate and feed grain demand with respect to feed prices and prices of individual livestock categories. Using feed demand parameters by livestock category enables analysts to evaluate policy effects of changes in feed demand quantities and feed costs within the livestock economy as well as to provide more reliable estimates of the total change in feed demand quantities.

**TABLE 4.  Elasticities of Concentrate and Feed Grain Feed Demand with Respect to Corn and Livestock Price by Livestock Category.**[a]

| Livestock Category | Elasticity of Feed Demand for Concentrates wrt. | | Elasticity of Feed Demand for Feed Grains wrt. | |
|---|---|---|---|---|
|  | Corn Price[b] | Livestock Price | Corn Price[b] | Livestock Price |
| Cattle and Calves | −.834 | .894 | −.948 | .894 |
| Hogs | −.051 | .132 | −.143 | .041 |
| Sheep | −.222 | .566 | −.231 | .336 |
| Chickens | −.180 | .180 | −.182 | .047 |
| Turkeys | −.069 | .197 | −.168 | .100 |
| Eggs | −.122 | .153 | −.228 | .147 |
| Milk | −.080 | .080 | −.158 | .075 |

[a] All elasticities are computed at 1961-1974 variable means using the parameters in Tables 1 and 2 and the formula presented by Allen [p. 252].

[b] Corn price is used as a measure for feed grain prices since corn is the dominant feed grain and the prices of other feed grains are highly associated with corn prices.

## References

Ahalt, J. Dawson and Alvin C. Egbert. "The Demand for Feed Concentrates: A Statistical Analysis." *Agricultural Economics Research*, 17 (1965): 41-49.

Allen, R. G. D. *Mathematical Analysis for Economists.* New York: St. Martins Press, 1938.

Brandow, G. E. *Interrelations Among Demands of Farm Products and Implications for Control of Market Supply.* Pennsylvania Agr. Exp. Sta. Res. Bul. 680, 1961.

Butell, Robert and Abner Womack. "October-December Feed Demand for Corn." USDA, ERS *Feed Situtation,* November, 1975.

Chuang, Y. H. "Estimation of Sector and Spatial Equilibrium Models of the United States Feed Economy." Ph.D. thesis, University of Illinois, 1961.

Feltner, Richard Lee. "Alternative Models of the Feed-Livestock Sector." Ph.D. thesis, North Carolina State University, 1965.

Foote, R. J. *Statistical Analysis Relating to the Feed Livestock Sector.* USDA Tech. Bul. 1070, June, 1953.

Fox, Karl A. and Richard C. Tauelber. "Spatial Equilibrium Models of the Livestock-Feed Economy." *Amer. Econ. Rev.* 45 (1955): 584-608.

King, Gordon A. *The Demand and Price Structure for By-Product Feeds.* USDA Tech. Bul. 1183, 1958.

Leuthold, Raymond M. "On the Use of Theil's Inequality Coefficient." *Amer. J. Agr. Econ.* 57 (1975): 344-346.

Meinken, Kenneth W. *The Demand and Price Structure for Oats, Barley, and Sorghum Grains.* USDA Tech. Bul. 1080, 1953.

Mielke, Karl D. "Demand for Animal Feed." Ph.D thesis, University of Minnesota, 1973.

Ray, Daryll E. *Revised Manual for Martin's Computer Algorithm for Estimating the Parameters of Selected Classes of Non-Linear Single Equations Models.* Oklahoma Agr. Exp. Sta. Res. Report P-674, 1972.

Theil, Henri. *Applied Economic Forecasting.* Chicago: Rand McNally and Company, 1966.

U.S. Department of Agriculture. *Agricultural Statistics, 1976.* Washington: U.S. Government Printing Office. 1976.

————. *Livestock-Feed Relationships National and State.* ERS, Commodity Economics Division, Supplement For Statistical Bulletin 530, 1975.

Womack, Abner. *The U.S. Demand for Corn, Sorghum, Oats, and Barley: An Econometric Analysis.* Department of Agricultural Economics Report 76-5, University of Minnesota, 1976.

## Appendix

Feed demand by the seven major livestock categories constituted about 82 percent of feed grains and total concentrates in the U.S. between 1960 and 1974. The residual portion is fed to horses, mules, fur bearing animals, dogs, game birds, etc. The residual feed needs to be estimated in order to use the equations presented in the text to estimate total feed demand. Residual feed demand is hypothesized to be a function of the index of prices received for livestock, feed grain prices, the number of grain consuming animal units, a time trend and an error term. This general functional form was used by Ahalt and Egbert for estimating aggregated livestock feed grain demand and total concentrate feed demand.

The ordinary least squares equations for residual feed grains and total concentrates fed to other livestock are presented below:

Other livestock feed demand for feed grains$_t$

$1211.6227 + 0.0849$ IPL$_t$ $- 1.1864$ CP$_t$ $- 0.6160$ T

t                  2.23            0.333         1.517

$F = 6.72$   $R^2 = .65$   S.E. $= 3.26$   $D = 2.31$   $\bar{Y} = 24.6$

Other livestock feed demand for total concentrates$_t$

$679.9811 + 0.0880$ IPL$_t$ $- 3.8231$ CP$_t$ $- 0.3398$ T

t                  2.209            1.027          0.801

$F = 5.55$   $R^2 = .60$   S.E. $= 3.41$   $D = 2.22$   $\bar{Y} = 33.6$

where: IPL$_t$ is the index of prices received for livestock 1910-14 $= 100$; CP$_t$ is average price of corn received by farmers; T is time in years, 1960, 1961, . . ., 1974. Grain consuming livestock production units were statistically insignificant and associated with the incorrect sign when included in the equations, so they were omitted.