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by

Mark R. Weimar and Richard P. Stillman

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A LONG TERM FORECASTING MODEL OF THE LIVESTOCK AND POULTRY SECTORS

Mark R. Weimar and Richard P. Stillman[1]

INTRODUCTION

An annual econometric model of the livestock and poultry sectors was estimated and used as the basis for a dynamic simulation model. The simulation model provides a framework to estimate the long-term impacts of legislative policy or exogenous shocks on the livestock and poultry sector. The model will also play a role in determining the livestock and poultry long-term forecast. The livestock and poultry long-term forecast is just one part of the USDA budget analysis which is used by different government agencies in their long-term budgeting process.

The econometric and simulation models were estimated within limitations set by the long-term forecast process. The process is iterative in that analysts for each sector involved provides initial estimates of their commodity quantities and prices. The initial results are furnished to any other sectors they may impact. For example, corn and soybean meal prices are estimated and provided to livestock and poultry analysts. Livestock and poultry personnel then estimate production and prices which are returned to crops where changes in feed use are incorporated and a second set of feed price estimates may be developed. A macroeconomic forecast furnishes estimates of exogenous variables such as consumer expenditures, disposable income, and inflation. Thus, the estimated model specifically uses variables which are estimated and provided exogenously by the process.

Beyond the need for an internal simulation model, many developments in the 1980's call into question previous models of the livestock sector. Until the 1980's, almost every part of the meat sector was growing. With the beginning of the 1980's, per capita beef consumpiton declined and leveled off at about 100 pounds carcass-weight. Before 1980 beef consumption climbed higher in each cycle. Only after the last cycle peak in 1976 beef production declined and leveled off. Whether a new cycle is in the offing is yet unanswered.

Also in the 1980's, poultry production accelerated, especially for broilers and turkeys. During the last half-decade, real prices of broilers and turkeys deviated from their traditional price to quantity relationship; prices of both commodities remained steady or, actually increased at times, as per capita consumption increased. Many reasons have been found to account for these changes. They are outlined in Stillman and Weimar.

This paper is organized into discussions of the model structure, data sources, results, validation, and the impact of an exogenous feed price shock on the livestock sector over a ten year horizon.

PREVIOUS STUDIES

Many previous articles describing estimating techniques for partial models of the livestock and poultry sector can be found in the literature. The USDA has several quarterly models which are used in short-term policy analysis. In addition models explicitly ignore consumer demand and use instead ad hoc derived demand models (Folwell and Shapouri, Stillman, Westcott and Hull, Westcott et al.). Most of articles that do include retail demand describe only partial models (Chavas), and therefore, are not corrected for cross-correlation error in the estimates of their parameters. Westcott (1986) estimates price changes at retail and resulting farm- and wholesale-level price changes assuming the quantities exogenous for the policy impact.

MODEL STRUCTURE

The 50 equation econometric model of the livestock and poultry sector specifies production, supply and demand endogenously and exogenously incorporates the macroeconomy and feed sectors. Figure 1 illustrates the main components of the model and flow of action and reaction. In simplest terms, four production sectors; beef, pork, broilers, and turkeys provide meat supplies to the demand

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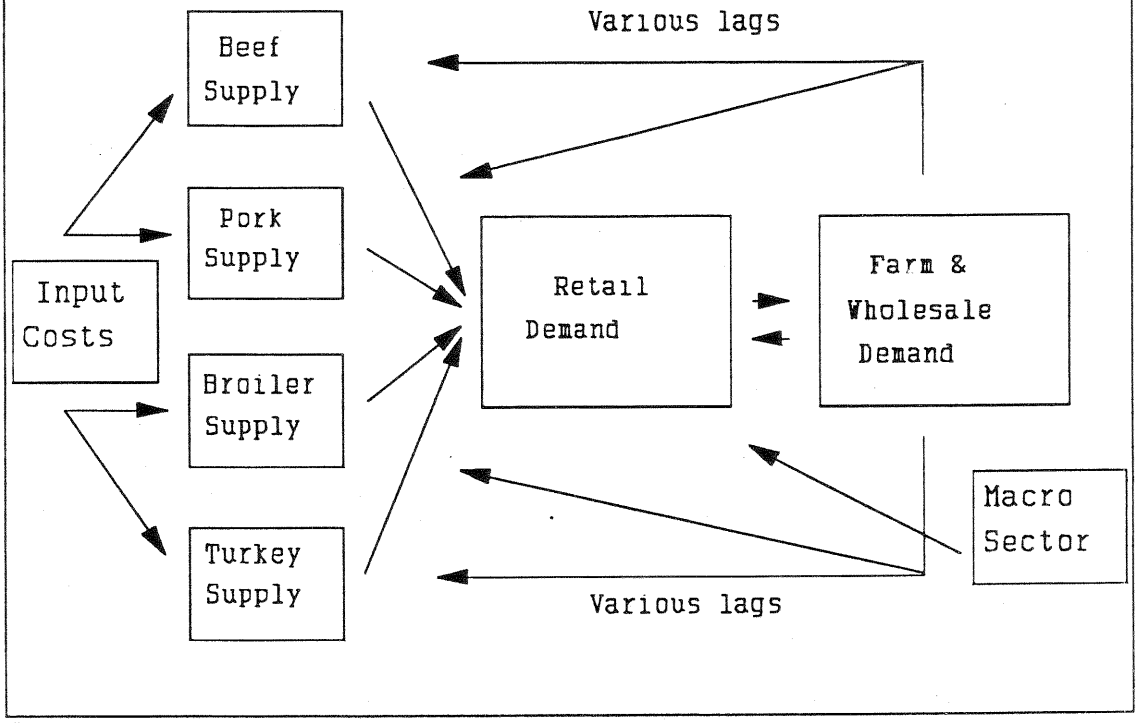
[1]*Agricultural economists with the Commodity Economics Division, Economic Research Service, U.S. Department of Agriculture*

sector. The demand sector is separated into two parts: a consumer demand submodel which determines retail prices and a derived demand submodel for the farm- and wholesale-level prices.

Figure 1. Model Structure



The model was simultaneous in the demand equations as per capita consumption and prices were determined simultaneously. The feedback to production is provided by lagged prices in the inventory (capital stock) equations.

Supply

All of the production sector parameters were estimated using consistent methodology. Only data limitations prevented the same model specification from being used in each of the four sectors. The inventory (production capital investment) equations drive the supply side. The producer response to profitability, proxied by an approximation of net returns, were used to estimate capital inventories such as the beef cow herd or the poultry supply flock. Most inventory equations contained a lagged endogenous variable. The rest of the equations specified the level of production given the production capacity defined by the inventories. See tables 1 and 2 for equations and parameter estimates.

Stocks were treated exogenously because even though parameters explaining stocks were significant, the equations explained little of the variation in an annual framework especially in poultry. Net international trade was treated as exogenous due to memory limitations in PC SAS on the size of the model. The model was estimated using real prices in the production sectors and normalized prices in the demand sector unless otherwise stated.

Demand

Retail demand was estimated using Huang's (1989) inverse demand system. The conceptualization of our submodel was identical but the endogenous variables that are estimated are different because of the additional detail needed for the pork, broilers, and turkey sectors in the long term policy analysis project. Huang estimated demand for the variables beef and veal, pork and

other red meats, and for poultry, we estimated demand for beef and veal, pork, frying chicken, and turkey as well as for nonfood items and food less meat items.

Wholesale prices were calculated as a spread based on the estimated CPI for the commodity, by-product credits, and by the level of production. The more production that comes to market, the lower the wholesale price and hence the wider the spread. Farm and feedlot beef prices were derived as a spread from the wholesale prices. The 7-market barrow and gilt price was derived from the pork retail CPI. Poultry wholesale prices were functions of their respective retail indices.

METHODOLOGY

The econometric model was estimated using two stage least squares (2SLS) in PC SAS to account for contemporaneous correlation between consumer prices and supplies and for the presence of lagged endogenous variables for the years 1960 to 1988. Individual sectors were estimated with 2SLS and the simulation model used the resulting parameter coefficients. Validation statistics were generated ex post and ex ante. For the out of sample validation, the individual submodels were estimated from 1960 to 1986, then the entire model was simulated from 1987 through 1989. Standard test statistics; such as mean percent error, mean absolute percent error, R-square, and Theil's statistical decomposition of U; were calculated and evaluated. The same statistics were used to evaluate the within sample estimates of the subsector models.

DATA

Annual retail CPI and price level data were obtained from the Bureau of Labor Statistics. The Economic Report of the President provided data on annual wages and consumer expenditures for food, nonfood and all items. The National Agricultural Statistics Service (NASS) of the USDA supplied most of the data for production and inventory items while the Agricultural Marketing Service (AMS) furnished most of the farm-level cattle and hog price data and the wholesale-level poultry prices.

The Department of Commerce reports export data. The Economic Research Service (ERS) releases several series using data from all of the previous sources including the carcass and retail weight per capita consumption series, and the 3-Region wholesale turkey price. Exact data definitions, calculations, and sources can be found in Appendix 1. Data sets were truncated to 1960 to 1988.

RESULTS

The estimated parameter coefficients and vital statistics of the model equations are shown in tables 1 and 2. Only selected parameter coefficients and variables will be discussed. In some cases, coefficients which were not significantly different from zero (alpha=.1) were included in the model because they were believed to be theoretically correct a priori and their inclusion significantly improved the forecasting ability of the model.

Beef Supply

The beef production sector was estimated with 14 equations defining the inventories of cows, heifers, and steers; the calf crop; slaughter of cows, heifers and steers; and average dressed weight. Slaughter multiplied by average dressed weight was equal to federally inspected production. Production was transformed into carcass weight per capita consumption.

The beef-cow herd equation, included a lagged endogenous variable, a quadratic form of returns above cash costs for cow-calf producers lagged 2 periods and the ratio of the all heifer inventory to heifer slaughter lagged 1 period. Hay prices lagged 1 period was used to proxy forage supply. Hay price was insignificant.

The calf crop depended upon the total cow herd size, the number of beef replacement heifers and cow-calf returns over cash costs lagged two periods. The equation fit relatively well.

The steer inventory, all heifer inventory, other heifer inventory, replacement heifer inventory, and the heifers, steers, and bulls less than 500 pounds inventory equations were dependent upon previous year's calf crop less the previous year's veal slaughter and a time trend.

The other heifer inventory and the beef replacement heifer inventory were also estimated with hay prices lagged one period. The hay price coefficient was insignificant for the beef replacemnet heifer equation but of the expected sign. As hay price increased, beef heifer replacements declined. The other heifer inventory included heifers most likely to be slaughtered. Thus as hay prices rise this inventory should rise as producers increase the number heifers on feed.

The other heifer inventory was also dependent on the cow-calf returns above cash costs. As returns rise producers are more likely to keep heifers for replacement. The coefficient was insignificant.

The bull inventory was a function of the number of all cows and a time trend. Bull slaughter was a function of cow slaughter. Steer slaughter depends on calves available after calf slaughter and the ratio of feedlot costs to grass costs as proxied by the hay price. The ratio reflects the opportunity cost of feeding versus not feeding.

Heifer slaughter was a function of the calves remaining after veal slaughter, the milk cow inventory, the returns over cash costs for cow-calf producers and dummy variables for 1984, 1986, and 1987. The dummies, which reflect droughts and dairy termination programs, were all insignificant.

Beef-cow slaughter depended on beef cow inventory, returns above cash costs for cow-calf producers, the ratio of beef heifer replacements kept to the beef cow inventory and dummy variables for 1983, 1984, 1986, and 1987. The dummies, which were intended to remove droughts and dairy termination program effects, were insignificant in 1986 and 1987.

Average dressed weight depended on the ratio of cow slaughter to total cattle slaughter, the hay price, log of time trend, a dummy for 1980 multiplied by the log of time trend, and the ratio of dairy cow slaughter to total cow slaughter. The negative sign on hay price reflects more cow slaughter with high hay prices and droughts, thereby, lowering average dressed weights.

Pork Supply

Pork supply was defined by six equations. Sows farrowing, the capital investment equation, was a function of net returns lagged 1 year, and sows farrowing lagged 1 period.

Barrow and gilt slaughter was a function of sows farrowing multiplied the number of pigs-per-sow-per-litter (pig crop) and the percent of commercial hog slaughter federally inspected. The percentage federally inspected has been increasing over time. Federally inspected slaughter has risen over time while the pig crop reported in the Hogs and Pigs report covers all pigs farrowed. This variable reflected that change.

Sow slaughter was dependent upon the number of sows farrowing and log trend. Boar slaughter was a function of sows farrowing. The average dressed hog weight depended on sow slaughter divided by the total slaughter, hog net returns lagged 1 period and a time trend. As hog net returns fall, producers will push forward their marketings, lowering the average dressed weight. The coefficient for hog net returns was marginally insignificant.

Total production was determined by multiplying average dressed weight by slaughter and dividing by the fraction of commercial slaughter that was federally inspected. Production was then transformed to per capita consumption.

Broiler Supply

The broiler production sector was estimated using five equations. The average hatchery supply flock equation was a funcition of a lagged endogenous variable, the 12-city broiler price and farm corn prices lagged 1 period and eggs per 100 hens lagged one year. The eggs per hen variable was included to indicate the changing productivity of the broiler hatching egg flock. It probably better reflects the trend to a larger and larger flock.

Chick placements were a function of the hatchery supply flock size and slaughter depended on the number chicks placed for slaughter. A time trend squared indicated that over time more chicks were reaching slaughter as a function placements. Average broiler dressed weights were simply a function of time reflecting both technology and the demand for larger poultry parts. Total production and per capita consumption were calculated by the same method as for beef.

Turkey Supply

Turkey supply was estimated with five equations. The size of the turkey flock was a function of a lagged endogenous variable, the turkey feed price ratio lagged 2 periods, and the wage-price ratio lagged 1 and 2 periods.

The turkey industry appears to be more dependent on wages for the further processing of its meat than broilers or at least more responsive. (The feed price ratio was calculated by dividing the 3-region wholesale turkey price by calculated annual feed costs and was not the same as that reported in Agricultural Prices (USDA)). The second lag on the ratio of turkey prices to wages was negative and significant, but was smaller than the positive value on the ratio lagged one period.

Turkey poult placements depended on the size of the turkey flock, a trend variable (1 divided by the year), and the feed efficiency ratio. The feed efficiency ratio captured the increasing productivity of poults but is a proxy for the increasing productivity of turkey hen breeders.

Average turkey dressed weights were mostly a function of time, but a set of dummies were used to adjust for a short period during the early 1970's when turkey producers tried to market a light type turkey for consumption during periods other than holidays. Average dressed weights during this period dropped.

Turkey slaughter varied directly with the number of poults placed for slaughter. Total production and per capita consumption were calculated in the same method as they were for beef.

Wholesale and Farm Demand

The wholesale boxed beef price and the cow carcass price were dependent upon the CPI for beef and veal, the wholesale beef by-product value, and the ratio of steer to cow slaughter. The ratio reflects the fact that as more steers than cows are slaughtered there will be additional demand for cows for use in hamburger. Thus, in the box beef equation the sign should be negative and vice versa in the cow carcass equation. In addition, the boxed beef price depends upon the change in beef production. The more beef pushed onto the market, the wider the spread. The change in beef production coefficient was insignificant. The wholesale beef by-product value was only marginally significant in the cow carcass equation with alpha equal to .10.

The Omaha fed steer and fed heifer prices were functions of the boxed beef price, the steer to heifer slaughter ratio and the farm beef by-product value. The sign on the steer to heifer slaughter ratio coefficient may not be intuitive to a nonlivestock analyst. The higher the heifer slaughter is, the more the beef cattle industry is under stress (less heifers are being kept for replacement). Thus, the more heifers slaughtered, the lower the ratio and the lower the fed steer and fed heifer prices relative to the wholesale value.

The Omaha cow price depended on the cow carcass price, the level of cow slaughter and the farm beef by-product value. The Kansas City feeder steer price depended on the Omaha fed steer price, the cost of feed and the size of the calf crop lagged one period. The calf crop variable was insignificant.

The 7-market barrow and gilt price was dependent upon the CPI for pork and the change in per capita pork consumption. As more pork comes to market, the lower the hog price.

The 12-city broiler price was a function of the frying chicken CPI, per capita consumption of broilers and time trend. The 3-region turkey and Eastern region hen turkey prices were functions of the index of retail whole frozen turkey prices, per capita turkey consumption and time trend. The trend variable indicates that the spread for broilers and turkeys grew wider with time in real terms reflecting perhaps the higher overhead of retail outlets.

Consumer Demand

The demand system consisted of five equations with percentage change in retail CPI for beef and veal, pork, frying chickens, turkey and nonfood, being the endogenous variables. All endogenous variables were a function of the percentage change in the Laspeyres index of quantities for beef, pork, broilers, turkeys, and nonfood and the scale variable using 1967 as the base. The scale variable was the indexed value of all consumption. The CPI values were all normalized by total consumer expenditures. The estimated parameters are compensated own-price and cross-price flexibilities. The estimated coefficients are shown in table 2.

The beef's own-price flexibility was negative and significant. This value was comparable to that obtained by Huang but was the only variable estimated similar to Huang. The only other significant coefficients were the own-price flexibilities for pork and turkey. The own-price coefficient for the frying chicken equation was marginally insignificant, with alpha equal to .16.

All the rest of the parameter coefficients were insignificant. Most coefficient signs were correct or relatively small. However, signs on parameters with respect to broilers and turkeys in the beef equation were positive when expected a priori to be negative.

The R-squares were not very high because the model was estimated on percentage changes. The highest R-square was associated with pork at .69 and the lowest with frying chicken at .30.

VALIDATION

Individual subsector model parameter estimates were obtained, for the period 1960-86, to test the forecasting ability of the simulation model as a system for the years 1987-89. Mean percentage error, mean absolute percentage error, and Theil's relative change U1 statistics are shown for the most important variables in table 3. Mean absolute percentage errors were tolerable after equations for turkey price and production, and beef cow carcass price and slaughter were corrected by adjusting their intercept values.

Mean percentage errors and mean absolute percentage errors were of the same magnitude for most variables indicating bias in the forecasts. The mean percentage error statistic should be near zero if there was no bias. Theil's U1 statistic for relative change indicated relatively few equations were as good as the naive forecast. The naive forecast is last year's value.

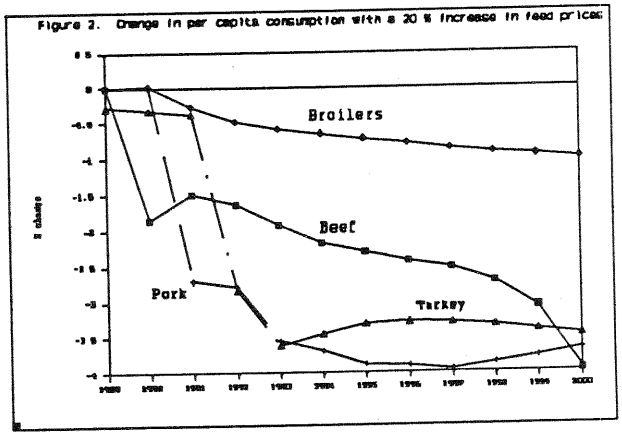
The best forecasting equations, using all three statistics, were prices for fed heifer and fed steer, Eastern hen turkey, beef and veal CPI, and all four production equations. Mean absolute percentage errors for these equations were below 3.0 percent except for the Eastern hen turkey price which had an 8.0 percent absolute error. The U1 statistic for the hen turkey price was below 1 indicating some wide variability in the price. Even though the mean absolute error was large, the model did a better job of forecasting than did last year's actual price.

The validation statistics indicate some of the turkey and broiler price equations need further investigation. The mean percent error statistics indicate that broiler production was under-forecast as were broiler prices while turkey production and price is over-forecast. This phenomenon is thought to be associated with changes in the poultry markets and in inadequate price data. Retail prices for turkeys and fryers are the only long-term series available for either commodity. But both commodities are sold in many different forms. The resulting under-prediction in price may be related to the value-added products which are being sold which bid up the price of the remain whole birds because there are actually fewer whole bird products being sold. Additionally retail demand positive cross-price flexibility coefficients for beef and pork with respect to chicken and turkey, respectively, could be causing the under- and over-forecasts. In general, we felt the model forecasted reasonably well out-of-sample.

CONSUMPTION AND PRICES CHANGES WITH A 20 PERCENT INCREASE IN FEED COSTS

The simulation model was used to make a 10-year forecast using current long-term policy forecast feed prices. A second forecast was produced using the feed prices increased by 20 percent. The results of that feed price shock are shown in figures 2 and 3.

Most of the results are as expected. But the results do indicate that some re-estimation of parts of the model are in order. One might postulate that beef consumption could drop immediately given the parameters in the beef production sector. However, the magnitude of the change is worrisomely large. Yet figure 2 shows that the shock does have the expected effect of at first dropping beef consumption and then raising it slightly from the previous period as more cows are slaughtered and herd size is reduced with the decreasing profitability. The shock sets off a reverse in the cattle cycle which does not end by the end of our ten year period.

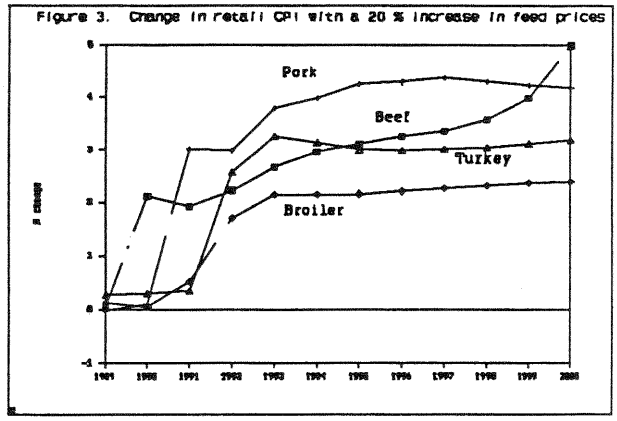


Other results of the forecast ouput indicate that the simulation model works from the policy perspective. Broiler per capita consumption falls less than all the other commodities while pork and turkey consumption fall relatively the same. Broilers are the most efficient converters of feed while pork and turkey are less efficient. The expected level of change in beef is indeterminate because ruminants can convert grass and hay instead of relying on grain. Retail price indices (figure 3) move as expected.

TOPICS FOR FURTHER RESEARCH

One of the more disappointing facets of the simulation model the estimated demand model. With insignificant signs for all variables but the own-price flexibilities, further investigation into the demand variables and equations are needed. The chicken own-price flexibility appears to be increasing in recent years, thus bringing into question the validity of a fixed flexibility model. It is also possible that the problem lies in the data rather than in the estimation method. See Stillman and Weimar. Further investigation will be done there. In addition, the dairy and egg industries will be estimated and included in the simulation model.

SUMMARY AND CONCLUSIONS



An annual forecasting model was estimated for the livestock and poultry sector using 2SLS for the period 1960 to 1986. The model had four production sectors; beef, pork, broilers, and turkeys, and the demand sector was separated into retail-, wholesale-, and farm-demand sectors. Retail demand was estimated using Huang's inverse demand system with restrictions applied for scale, symmetry and homogeneity. The wholesale- and farm-level demand sectors were estimated as derived demand sectors using spreads from the retail prices.

The parameters estimated in subsector models were inserted into a dynamic simulation model and the model validated for the years 1987-89. Results from forecasting out-of-sample indicated the model forecasted reasonably well. Kansas City feeder steer prices, 12-city broiler prices, the frying chicken CPI, and broiler production were forecasted better by the estimated simulation model than by the naive model. Mean absolute percentage errors were acceptable for most variables. Only turkey production, turkey prices, and the cow carcass price were unacceptably large.

Lastly, a policy shock was analyzed by forecasting to the year 2000 under current long-term policy forecast conditions and then with a 20 percent increase in feed prices. The results of the forecast were nearly as expected.

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Table 1--Estimation results for annual forecasting model

Parameter	Estimate	Approximate standard Error	'T' Ratio	Approximate Probability > |T|
Cattle Subsector Equations, Parameter Estimates, and Identities:				
Beef cow Inventory =				
Intercept	-220.571851	2436.2	-0.09	0.9286
Lag 1 beef cow inventory	1.106030	0.05706	19.38	0.0001
Lag 2 cow cash returns	27.813386	7.44752	3.73	0.0011
(Lag 2 cow cash returns)**2	-0.138278	0.05410	-2.56	0.0177
Lag 1 heifer slaughter / all heifer inventory	-6107.84	2961.3	-2.06	0.0506
Lag 1 hay price	-10.198426	35.19274	-0.29	0.7746
dfe = 23 Mean square error = 483910.1		R-square = 0.9831		
Calf crop =				
Intercept	14359.78	4924.3	2.92	0.0074
All cow inventory	0.428011	0.15866	2.70	0.0123
Beef heifers for replacement	1.447241	0.51536	2.81	0.0095
Lag 2 cow cash returns	7.679392	3.49290	2.20	0.0374
dfe = 25 Mean square error = 895649.9		R-square = 0.9095		
Steer inventory (500 > lb) =				
Intercept	5383.28	964.87387	5.58	0.0001
Lag 1 calf crop - calf slaughter	0.223518	0.02745	8.14	0.0001
Trend	50.336952	13.54136	3.72	0.0010
dfe = 26 Mean square error = 282413.7		R-square = 0.8453		
All heifer inventory (500 > lb) =				
Intercept	10099.25	1024.1	9.86	0.0001
Lag 1 calf crop - calf slaughter	0.150540	0.02913	3.53	0.0001
Trend	50.767419	14.37221	3.53	0.0016
dfe = 26 Mean square error = 318132.7		R-square = 0.7435		
Other heifer inventory (500 > lb) =				
Intercept	4263.40	708.65976	6.02	0.0001
Lag 1 calf crop - calf slaughter	-0.045141	0.01511	-2.99	0.0064
Lag 1 hay price	25.905395	7.31644	3.54	0.0017
Lag 1 cow cash returns	-0.840552	1.36308	-0.62	0.5433
Trend	99.430264	7.63461	13.02	0.0001
dfe = 17 Mean square error = 72298.4		R-square = 0.9120		

Table 1--Estimation results for annual forecasting model

Parameter	Estimate	Approximate standard Error	'T' Ratio	Approximate Probability > |T|
Cattle Subsector Equations, Parameter Estimates, and Identities (continued):				
Beef heifers for replacement =				
Intercept	-158.0698	952.39271	-0.46	0.6484
Beef cow inventory	0.205053	0.01895	10.94	0.0001
Lag 1 hay price	-15.9389	10.77270	-1.26	0.0001
dfe = 25	Mean square error = 180518.7	R-square = 0.8458		
Bull inventory (> 500 lbs.) =				
Intercept	-1058.40	183.85410	-5.76	0.0001
All cow inventory	0.062555	0.0037679	16.60	0.0001
Trend	14.980219	1.47848	10.13	0.0001
dfe = 26	Mean square error = 4399.2	R-square = 0.9412		
Heifers, steers, and bulls (< 500 lb.) =				
Intercept	-24022.84	1782.7	-13.48	0.0001
Lag 1 calf crop - calf slaughter	1.106872	0.04076	27.15	0.0001
Lag 1 hay price	93.988481	18.36223	5.12	0.0001
dfe = 26	Mean square error = 754965.6	R-square 0.9727		
Steer slaughter =				
Intercept	3947.06	1439.5	2.74	0.0109
Lag 1 calf crop - calf slaughter	0.444621	0.03342	13.31	0.0001
Ratio feedlot costs to grass feeding costs	-23653.65	3555.8	-6.65	0.0001
dfe = 26	Mean square error =51360.0	R-square = 0.8807		
Heifer slaughter =				
Intercept	27537.88	1969.8	13.98	0.0001
Lag 1 calf crop - calf slaughter	-0.153578	0.03233	-4.75	0.0001
Milk cow inventory	-1.010724	0.05797	-17.43	0.0001
Cow cash returns	-12.899904	1.39697	-9.23	0.0001
Dummy 1984	-162.154194	357.15441	-0.45	0.6543
Dummy 1986	450.361338	375.28923	1.20	0.2429
Dummy 1987	-509.658713	654.69948	-0.78	0.4446
dfe = 22	Mean square error = 111713.0	R-square = 0.9817		
Beef cow slaughter =				
Intercept	884.272839	2816.3	0.31	0.7568
Beef cow inventory	0.139859	0.02447	5.71	0.0001
Cow cash returns	-8.499540	3.05096	-2.79	0.0114
Hay price	11.233567	17.64988	0.64	0.5317
Beef heifers for replacement / beef cow inventory	-21071.59	11834.0	-1.78	0.0902
Dummy 1983	250.115719	589.12293	0.42	0.6757
Dummy 1984	1606.76	569.76363	2.82	0.0106
Dummy 1986	1207.46	644.68759	1.87	0.0758
Dummy 1987	1827.17	1195.9	1.53	0.1422
dfe = 20	Mean square error = 270160.4	R-square = 0.8534		
Bull slaughter =				
Intercept	-161.002920	82.73420	-1.95	0.0621
Cow slaughter	0.115658	0.01251	9.25	0.0002
dfe = 27	Mean square error = 11084.3	R-square = 0.7614		

Table 1--Estimation results for annual forecasting model

Parameter	Estimate	Approximate standard Error	'T' Ratio	Approximate Probability > |T|
Cattle Subsector Equations, Parameter Estimates, and Identities (continued):				
Average beef dressed weight =				
Intercept	598.436159	29.27056	20.44	0.0001
Cow slaughter / total cattle slaughter	-384.808993	74.58034	-5.16	0.0001
Hay price	-0.234943	0.21114	-1.11	0.2773
Log trend	42.178535	6.26257	6.74	0.0001
Dummy 1980 * log trend	2.979998	1.39903	2.13	0.0441
Dairy cow slaughter / total cow slaughter	-53.470329	21.47259	-2.49	0.0204
dfe = 23	Mean square error = 48.08375	R-square = 0.9487		
Total beef production = (Average dressed weight * total slaughter) / (fraction total slaughter federally inspected)				
Per beef capita consumption =(Total production + net trade - change in stocks) / (population)				
Hog Subsector Equations, Parameter Estimates, and Identities:				
Sows farrowing =				
Intercept	77.171019	1769.0	0.04	0.9655
Lag 1 sows farrowing	0.928661	0.13461	6.90	0.0001
Lag 1 hog net returns	76.183292	17.74085	4.29	0.0002
dfe = 26	Mean square error = 356133.9	R-square = 0.6528		
Barrow and gilt slaughter =				
Intercept	2992.67	5120.8	-0.58	0.5640
Pigs per sow	0.867804	0.05787	14.99	0.0001
Pigs per sow * fraction federally inspected	-1.447141	0.08526	-16.97	0.0001
dfe = 27	Mean square error = 3627386.1	R-square = 0.9435		
Sow slaughter =				
Intercept	-1926.23	1299.1	-1.48	0.1497
Sows farrowing	0.533392	0.10535	5.06	0.0001
dfe = 27	Mean square error = 290441.0	R-square = 0.4871		
Boar and stag slaughter =				
Intercept	1210.30	246.56768	4.91	0.0001
Sow slaughter	-0.119677	0.05259	-2.28	0.0310
dfe = 27	Mean square error = 42116.7	R-square = 0.1567		
Average pork dressed weight =				
Intercept	125.498657	9.48988	13.22	0.0001
Sow slaughter / total slaughter	479.294261	95.58761	5.01	0.0001
Lag 1 hog net returns	-0.011697	0.05390	-0.22	0.8300
Trend	0.692909	0.14627	4.74	0.0001
dfe = 25	Mean square error = 4.63613	R-square = 0.4440		
Total pork production = (Average dressed weight * total slaughter) / fraction of total slaughter federally inspected)				
Per capita pork consumption =(Total production + net trade - change in stocks) / (population)				

Table 1--Estimation results for annual forecasting model

Parameter	Estimate	Approximate standard Error	'T' Ratio	Approximate Probability > |T|
Broiler Subsector Equations, Parameter Estimates, and Identities:				
Hatchery supply flock =				
Intercept	-56753.22	30401.6	-1.87	0.0742
Lag 1 hatchery supply flock	1.060379	0.48954	2.17	0.0405
Lag 1 12-city broiler price	189.970375	107.63581	1.76	0.0903
Lag 1 farm corn price	-1343.05	467.65802	-2.87	0.0084
Lag 1 eggs per 100 hens	2.019602	0.62787	3.22	0.0037
dfe = 24 Mean square error =	2237072.7	R-square = 0.8558		
Broiler chick placements =				
Intercept	-5220998.31	226391.0	-23.06	0.0001
Hatchery supply flock	91.911112	16.50402	5.57	0.0001
Poultry trend	88417.08	6133.2	14.42	0.0001
dfe = 26 Mean square error =	1.87601E10	R-square = 0.9834		
Average broiler dressed weights =				
Intercept	3.546638	0.32213	11.01	0.0001
Poultry trend	-0.048535	0.0087839	-5.53	0.0001
(Poultry trend)**2	0.00050189	0.00005928	8.47	0.0001
dfe = 26 Mean square error =	0.0003980	R-square = 0.9925		
Slaughter =				
Intercept	-871800.95	61885.2	-14.09	0.0001
Chick placements	0.595684	0.05665	10.52	0.0001
(Poultry trend)**2	345.954895	45.72170	7.57	0.0001
dfe 26 Mean square error =	1503740917	R-square = 0.9987		
Federally inspected broiler production = slaughter * average dressed weight				
Per capita broiler consumption = ((federally inspected production * adjustment factor) - (condemnations of further processed and cutup meat) - (change in stocks + exports) / population				
Turkey Subsector Equations, Parameter Estimates, and Identities:				
Turkey flock =				
Intercept	-991374.71	517271.4	-1.92	0.0673
Lag 1 turkey flock	0.638138	0.16351	3.90	0.0007
Lag 2 turkey price/feed cost	507180.31	109729.1	4.62	0.0001
Lag 1 turkey price/farm wage	2804672.74	547503.4	5.12	0.0001
Lag 2 turkey price/farm wage	-1701530.40	530374.8	-3.21	0.0038
dfe = 24 Mean square error =	8.35074E10	R-square = 0.7830		
Turkey poult placements =				
Intercept	12982328	708044.3	18.34	0.0001
Turkey flock	0.027397	0.0036332	7.54	0.0001
1 / year	-25576229	1418842.1	-18.03	0.0001
Feed efficiency ratio	8397.02	3499.7	2.40	0.0242
dfe = 25 Mean sqare error =	57027284	R-square = 0.9745		
Average dressed weight =				
Intercept	-9.758430	1.66237	-5.87	0.0001
Square root of trend	2.992966	0.20841	14.36	0.0001
Dummy (1970-74)	638.331535	196.70989	3.25	0.0034
Dummy (1970-74) * year	-0.324203	0.09977	-3.25	0.0034
Dummy (1975-88) * year	-0.00097197	0.0001180	-8.24	0.0001
dfe = 24 Mean square error =	0.02799	R-square = 0.9572		
Turkey slaughter =				
Intercept	-15714.81	3073.6	-5.11	0.0001
Poult placement	0.955794	0.01920	49.78	0.0001
dfe = 27 Mean square error =	20025897	R-square = 0.9894		

Table 1--Estimation results for annual forecasting model

Parameter	Estimate	Approximate standard Error	'T' Ratio	Approximate Probability > |T|
Turkey Subsector Equations, Parameter Estimates, and Identities (continued):				
Federally inspected turkey production = slaughter * average dressed weight				
Per capita consumption =(Federally inspected production * adjustment factor) - (condemnations of further processed and cutup meat)+ - (change in stocks + exports) / (population)				
Farm and Wholesale Demand Equations:				
Box beef wholesale price =				
Intercept	-21.925595	14.14555	-1.55	0.1348
Retail beef and veal cpi	1.320841	0.19636	6.73	0.0001
Change in beef production	-0.00016305	0.0010679	-0.15	0.8800
Wholesale beef by-product value	6.002558	2.30769	2.60	0.0160
Steer slaughter / cow slaughter	-7.152226	2.72415	-2.63	0.0151
dfe = 23	Mean square error = 26.53728	R-square = 0.9301		
Cow carcass price =				
Intercept	-67.464330	19.87961	-3.39	0.0024
Retail beef and veal cpi	1.063127	0.28191	3.77	0.0009
Wholesale beef by-product value	5.683178	3.35387	1.69	0.1031
Steer slaughter / cow slaughter	12.477736	4.05519	3.08	0.0052
dfe = 24	Mean square error = 58.83085	R-square = 0.8612		
Omaha fed steer price =				
Intercept	-7.352762	3.54592	-2.07	0.0490
Box beef wholesale price	0.514456	0.03921	13.12	0.0001
Steer slaughter/ heifer slaughter	5.459265	1.58510	3.44	0.0021
Farm beef by-product value	0.492782	0.15792	3.12	0.0047
dfe = 24	Mean square error = 5.88206	R-square = 0.9616		
Omaha fed heifer price =				
Intercept	-3.387148	3.66843	-0.92	0.3650
Box beef wholesale price	0.448089	0.04056	11.05	0.0001
Steer slaughter/ heifer slaughter	6.205223	1.63986	3.78	0.0009
Farm beef by-product value	0.521992	0.16338	3.19	0.0039
dfe = 24	Mean square error = 2.40647	R-square = 0.9767		
Omaha cow price =				
Intercept	8.178780	2.58126	3.17	0.0041
Cow carcass price	0.383835	0.02479	15.48	0.0001
Cow slaughter	-0.00086471	0.0002267	-3.82	0.0008
Farm beef by-product value	0.500878	0.11067	4.53	0.0001
dfe = 24	Mean square error = 6.29552	R-square = 0.9517		
Kansas City feeder steer price =				
Intercept	-3.525568	6.2881	-0.56	0.5801
Omaha fed steer price	0.990019	0.06600	15.00	0.0001
Feed cost	-1.736904	0.33794	-5.67	0.0001
Lag 1 calf crop	0.00049479	0.0004477	1.11	0.2800
dfe = 24	Mean square error = 24.782203	R-square = 0.9015		

Table 1--Estimation results for annual forecasting model

Parameter	Estimate	Approximate standard Error	'T' Ratio	Approximate Probability > |T|
Farm and Wholesale Demand Equations (continued):				
7-market barrow and gilt =				
Intercept	-43.279504	3.85483	-11.23	0.0001
Retail pork cpi	0.906809	0.03377	26.85	0.0001
Change in pork production	-0.00259450	0.0004351	-5.96	0.0001
dfe = 25 Mean square error = 5.75270		R-square = 0.9725		
12-city wholesale broiler price =				
Intercept	-3.165852	10.88073	-0.29	0.7735
Retail whole fryers cpi	0.581192	0.04916	11.82	0.0001
Per capita broiler consumption	-1.233291	0.20410	-6.04	0.0001
(Poultry trend)**2	0.00857233	0.0015299	5.60	0.0001
dfe = 25 Mean square error = 2.26487		R-square = 0.9934		
3-Region wholesale turkey price =				
Intercept	-94.833248	49.51828	-1.92	00670
Index of retail frozen Turkey price	1.106155	0.19410	5.70	0.0001
Per capita turkey consumption	-0.686738	1.49647	-0.46	0.6503
(Poultry trend)**2	0.00781846	0.0036038	2.17	0.0398
dfe = 25 Mean square error = 37.96898		R-square = 0.9438		
Eastern region wholesale hen turkey price (nominal) =				
Intercept	12.890322	3.33569	3.86	0.0007
Index of retail frozen Turkey price (nominal)	0.798779	0.09319	8.57	0.0001
Per capita turkey consumption	-1.554925	0.72883	-2.13	0.0429
(Poultry trend)**2	-0.00148195	0.0024211	-0.61	0.5460
dfe = 25 Mean square error = 10.76085		R-square = 0.9511		

*, /, +, or - refer to multiply, divide, addition, subtraction, respectively
**2 = squared
Log = natural log
q = quantity

Table 2. Estimated demand coefficients 1/

Compensated price flexibility coefficient with respect to:

	Beef	Pork	Broilers	Turkey	Nonfood	Scale
Beef	-1.1857	-0.0945	0.1952	-0.0691	0.0003	-1.2776
Pork	-0.0571	-1.0066	-0.2201	0.0667	0.0003	-1.2952
Broilers	0.0345	-0.0643	-0.8490	-0.3623	-0.0002	-0.4841
Turkey	-0.0037	0.0059	-0.1089	-0.7937	0.0000	-0.3856
Nonfood	0.0078	0.0146	-0.0299	0.0108	-0.9667	-0.8671

1/ Only own-price coefficients for beef, pork, and turkey are significant.

Table 3. Selected validation statistics, 1987-1989 1/

Variable	Mean % Error	Mean Absolute % Error	Theil's Relative change U1 statistic
Boxed beef price	4.24	4.24	1.81
Cow carcass price	4.88	5.00	1.53
Omaha fed steer	0.78	1.92	1.24
Omaha fed heifer	-0.28	1.83	0.71
K.C. feeder steer	-4.17	4.17	1.02
7-mkt barrow and gilt	0.56	12.91	1.22
12-city broiler	-2.71	13.03	1.26
3-region turkey	11.32	11.31	1.30
Eastern hen turkey	6.50	7.92	0.40
Beef and veal CPI	2.12	2.12	0.64
Pork CPI	-2.95	4.17	1.10
Frying chicken CPI	-6.65	8.08	1.29
Turkey CPI	3.97	3.97	1.28
Beef production	-0.11	2.29	3.12
Pork production	0.97	2.66	0.21
Broiler production	-2.07	2.10	0.40
Turkey production	1.73	2.50	0.39

1/ Out of sample validation statistics

Appendix 1. Data definitions, calculations and sources

Beef cow inventory = Beef cows and heifers that have calved on January 1, NASS
Cow cash returns = Returns above cash costs for cow-calf producers, ERS
Heifer slaughter = The number of heifers slaughtered under federal inspection, NASS
All heifer inventory = All heifers on farms, 500 pounds and over on January 1, NASS
Calf crop = Calf crop, NASS
Calf slaughter = Number of calves slaughtered under federal inspection, NASS
Beef replacement heifers = Heifers, over 500 pounds for beef cow replacement on farms January 1, NASS
Steer inventory = All steers, over 500 pounds, on farms January 1, NASS
Hay price = All hay price, NASS
Other heifer inventory = Other heifers, over 500 pounds on farms January 1, NASS
Trend = Year - 1949;
Steer price = Omaha choice fed steer price, 900-1100 pounds, AMS
Heifer price = Omaha slaughter heifer price, 900-1100 pounds, AMS
Feeder steer price = Kansas City feeder steer price, 600-700 pounds, AMS
Heifers, steers, and bulls = Heifers, steers, and bulls under 500 pounds on farms, January 1, NASS
Bull inventory = All bulls over 500 pounds on farms, January 1, NASS
All cow inventory = Sum of beef cows and milk cows that have calved on farms on January 1, NASS
Milk cow inventory = Milk cows and heifers that have calved on farm, January 1, NASS
Steer slaughter = Number of steer slaughtered under federal inspection, NASS
Heifer slaughter = Number of heifers slaughtered under federal inspection, NASS
Bull slaughter = Bulls and stags slaughtered under federal inspection, NASS
Beef cow slaughter = Number of beef cows slaughtered under federal inspection NASS
Dairy cow slaughter = Number of dairy cows slaughtered under federal inspection, NASS
Total cow slaughter = Sum of dairy cow slaughter and beef cow slaughter, NASS
Total cattle slaughter = Sum of heifer, steer, total cow, and bull slaughter, NASS
Feedlot costs = (45 bu. of corn*corn price + 330 lbs. of hay*hay price +20 lbs. of soybean meal* soybean meal price)
Grass feeding costs = All hay price, NASS
Corn price = Marketing year average price of corn received by farms, NASS
Soybean meal price = Decatur 44% soybean meal price, NASS
Dummy 1980 = 1 in 1980, 0 elsewhere
Dummy 1983 = 1 in 1983, 0 elsewhere
Dummy 1984 = 1 in 1984, 0 elsewhere
Dummy 1986 = 1 in 1986, 0 elsewhere
Dummy 1987 = 1 in 1987, 0 elsewhere
Log trend = Natural log of trend
Average beef dressed weight = federally inspected production divided by federally inspected slaughter
Total beef production = Federally inspected beef production adjusted to account for on-farm consumption and other production, ERS
Per capita consumption = Carcass weight per capita consumption of beef, ERS

Appendix 1. Data definitions, calculations and sources (continued)

Sows farrowing = Sows farrowing, NASS
Hog net returns = Net returns above cash and replacement costs, ERS
Pigs per sow = Average pigs per litter, NASS
Barrow and gilt slaughter = Barrow and gilt slaughter under federal inspection, NASS
Sow slaughter = Sow slaughter under federal inspection, NASS
Boar slaughter = Boar slaughter under federal inspection, NASS
Average hog dressed weight = Federally inspected pork production divided by total federally inspected slaughter
Total pork production = Federally pork production adjusted for farm consumption and state inspected production, ERS
Per capita pork consumption = Carcass weight per capita consumption of pork, ERS
Hatchery supply flock = Annual average of the sum of pullets placed 7 to 14 months prior to a particular month, NASS
12-city broiler price = 12-city wholesale composite for whole broilers, AMS
Broiler chick placements = Broiler chicks hatched, NASS
Poultry trend = Year - 1900
Broiler slaughter = Young chickens slaughtered under federal inspection, NASS
Average broiler dressed weight = Federally inspected production divided by federally inspected slaughter
Federally inspected broiler production, NASS
Per capita broiler consumption = carcass weight per capita consumption of broilers, ERS
Turkey flock = Turkey flock inspected for pullorum disease, NPIP
3-region average turkey price = weighted average of commodity hen and and tom turkey prices in the East, West, and Central regions, derived from AMS data
Feed per pound of gain = ERS turkey feed costs in net returns calculation divided by feed cost base on farm corn price and 44 percent soybean meal price
feed cost = 70 % corn and 30 % soybean meal ration times feed per pound gain
(This may seem circular, but it was used to transform Illinois points corn prices and Decatur 49% soybean meal to the corn and meal prices given in the baseline.)
Farm wage = index of farm wages paid, Economic Report of the President
Price/feed cost = 3-region average turkey price divided by cost of turkey feed
Price/farm wage = 3-region average turkey price divided by farm wage
Turkey poult placements = Turkey poults placed for slaughter, NASS
Square root of poultry trend = square root of (year -1900)
Inverted trend = 1/year
Dummy (1970-74) = 1 for 1970 to 1974, 0 elsewhere
Dummy (1975-88) = 1 for 1975 to 1988, 0 elsewhere
Turkey slaughter = federally inspected turkey slaughter of all types, NASS
Turkey production = federally inspected turkey production of all types, NASS
Turkey average dressed weight = F.I. production divided by F.I. slaughter, NASS
Per capita turkey consumption = carcass weight per capita turkey consumption, NASS
Box beef wholesale price = Choice box beef wholesale price, AMS
Cow carcass price = Utility cow carcass price, AMS
Omaha cow price = Price utility cows in Omaha, AMS
7-market barrow and gilt price, AMS
Eastern region wholesale hen turkey price, AMS
Beef and veal CPI = Retail price index for beef and veal (1982-84=100), BLS
Pork CPI = Retail price index for pork (1982-84=100), BLS
Whole frying chicken CPI = Retail price index for frying chicken, (1982-84=100), BLS
Frozen whole turkey retail index = an index of whole frozen turkeys based average price in 1982 to 1984 data, derived from BLS data
CPI for all items less food, BLS
Scale = Laspeyres index of value of all consumption, base year = 1967

NASS = National Agricultural Statistics Service, USDA
AMS = Agricultural Marketing Service, USDA
BLS = Bureau of Labor Statistics
ERS = Economic Research Service