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A QUARTERLY MODEL OF THE LIVESTOCK INDUSTRY
STILLMAN, R P   1 OF 1

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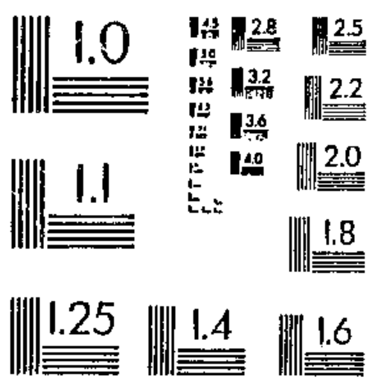

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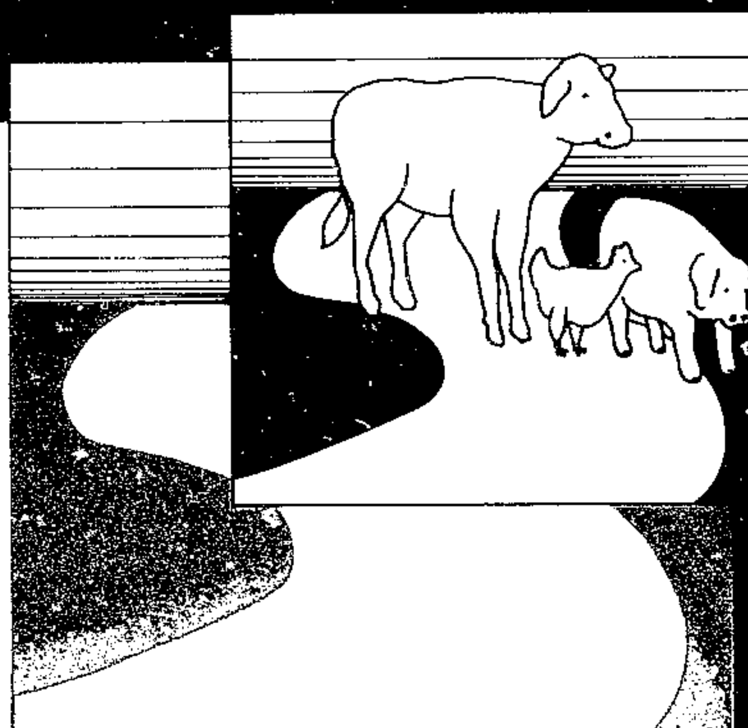
A Quarterly Model of the Livestock Industry

Richard P. Stillman



A Quarterly Model of the Livestock Industry. By Richard P. Stillman, National Economics Division, Economic Research Service, U.S. Department of Agriculture. Technical Bulletin No. 1711.

Abstract

A newly developed model for the U.S. livestock industry provides quarterly forecasts of livestock prices and quantities and is used in impact analysis where alternative scenarios are simulated and compared with the model's base forecast. The model incorporates both behavioral and biological equations to project beef, pork, and broiler quantities and prices used by outlook and situation analysts. The model is estimated over the period 1970-81 using OLS (ordinary least squares) estimation procedure. The model is also evaluated for the period 1982-84 to test its performance outside the data base. The model's performance was acceptable given the conditions affecting the livestock sector during the periods studied.

Key words: Livestock econometric model, forecasting, beef, pork, broilers, outlook and situation analysis.

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Summary

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The model incorporates both behavioral and biological equations to project beef, pork, and broiler quantities and prices used by outlook and situation analysts. The model is used to analyze the behavior of both the producers of meat animals and the consumers of meat products.

The model is an improvement over other livestock models because it incorporates cost expectations. Consumers purchase products according to their preferences, relative prices, and their income. Their purchases cause wholesalers and retailers to adjust prices to clear the market. Increasing and decreasing retail price expectations cause marketing agents to adjust their input price bids to animal producers. The animal producers then adjust their production according to both their price and cost expectations.

A Quarterly Model of the Livestock Industry

Richard P. Stillman*

Introduction

Forecasting livestock prices and quantities over the past several years has been increasingly affected by outside influences. Analysts must consider an increasing amount of information, since prior models are too narrow to provide all the information necessary.

This report describes in detail a livestock model developed to aid situation and outlook analysts in developing and analyzing different scenarios. This econometric model will also aid economists in disseminating information and creating forecasts. The model was estimated for the period 1970-81 from the data sources outlined in app. table 1. The model includes equations dealing with production and consumption of beef, pork, and broilers. Both the underlying structure and results of the estimation are presented. The model is then validated for 1973-81 and for 1982, 1983, and 1984.

The meat complex is vital to the agricultural economy because it is a major user of agricultural products and because it produces an important final agricultural output. Livestock and poultry production used 45 percent of the feed grain supplies and 4 percent of the oilseed supplies in 1982. Animal production accounted for $70.2 billion, or 49 percent of agricultural cash receipts, in 1982. This amount does not include the value added by the marketing agents who transform these raw agricultural products into the final consumer product. Value added by meat-packers, processors, and retailers in 1982 was 48 percent of the retail price.

Finally, consumers spend about 4 percent of their disposable income on red meat and poultry products (an important source of protein and minerals), accounting for 30 percent of the consumer food budget.

Analysis of the meat complex involves compiling, processing, and disseminating the massive amount of information internal and external to the meat complex itself. Both demand and supply for the raw and final products depend not only on the agricultural sector, but on the U.S. economy and the world economy as well. Livestock and poultry producers have always competed with each other for inputs and financing. The entire agricultural sector now increasingly faces a worldwide market for feeds and capital. Meat products also compete with each other as sources of protein, and with other goods and services for the consumer dollar. The economy affects the financial aspects of livestock and poultry production, the supply and cost of money, and consumer ability to purchase goods and services.

Commodity situation and outlook forecasting work relies on an analyst's ability to process and disseminate all this information. Beyond the noetic processes, the analyst needs other tools to assemble and process this wealth of information efficiently. A behavioral econometric model is one of these tools. An econometric model can establish a consistent set of structural parameters which help identify historical behavioral patterns. Information gained from identification of these behavioral patterns is useful in projecting the future in two ways: first, by identifying where the problems have arisen in the past and the causes of these problems, and second, by using the parameters to forecast expected values.

Analysts are often required to develop forecasts and "what if" scenarios. Econometric models are also

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useful for this purpose. A base forecast can initially be developed using the model and prior knowledge of the analysts. Alternative scenarios can then be postulated to determine differences from this base solution.

This quarterly livestock and poultry model was developed by emphasizing identification of a structural model to aid the outlook analyst in making decisions. Structural soundness was important because of the need to capture the major influences affecting the industry. Identifying underlying causes of movement in the marketplace was given the highest priority. Therefore, direction accuracy rather than point accuracy was emphasized.

Model Structure

Several important characteristics were identified and incorporated into the model. Biology imposes major constraints anytime a model deals with an agricultural phenomenon. Some biological constraints can be overcome gradually by genetic engineering to improve crop yields or develop a better breed of animal, or by better nutritional and management practices to improve gains in the feeding process. Some biological factors are relatively invariant, however, such as the length of the gestation periods of animals. Recognizing these factors and identifying their effect on industry behavior is a first step in developing an agricultural model. Figures 1, 2, and 3 illustrate the timeframe for livestock and poultry production. Cattle have the longest reproductive cycle, followed by hogs and broilers.

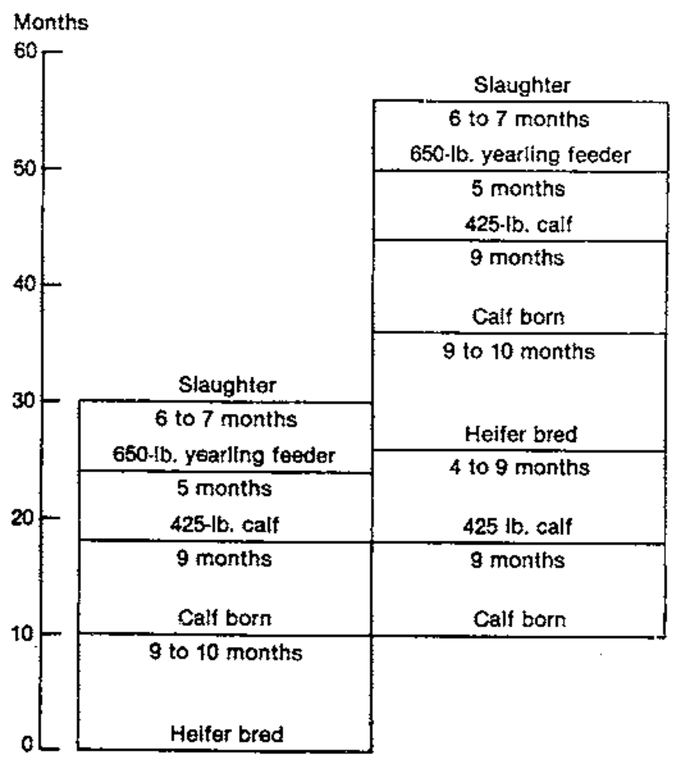
After establishing the biological factors in the structure of the model, the next step is to identify the points in the process where decisions are made and the factors on which these decisions are based. Within the livestock and poultry complex, the production process is usually longer than the quarterly timeframe of this model. Decisions must thus be made on expected returns to the production process.

Outlook and situation work is usually done within a quarterly timeframe for several reasons. First, sufficient intrayear analysis can be done to benefit market participants and policymakers. Second, a large amount of information is only available on a quarterly basis. One advantage of a quarterly data period is that the structure of the model becomes recursive as a result, easing computational problems of a large simultaneous model.

The flow of causality in a modeled phenomenon affects the choice of the model structure. Causality within a model generally becomes more unidirectional the shorter the length of the data period. Because the model deals with physical livestock growth over time, producers must commit resources based on expectations of returns, and decisions that affect resource allocations cannot be altered for several periods. Therefore, causality is unidirectional and the recursive system approach is proper. In the case of cattle, the period from the time of conception of the calf until the steak reaches the consumer averages 26-28 months. Because the model deals with a process which involves physical growth, producers form expectations about returns, making decisions affecting inputs which cannot be altered for several periods. A decision once made becomes a "sunk cost"; further alternatives of production are based on marginal decision criteria.

Figure 1

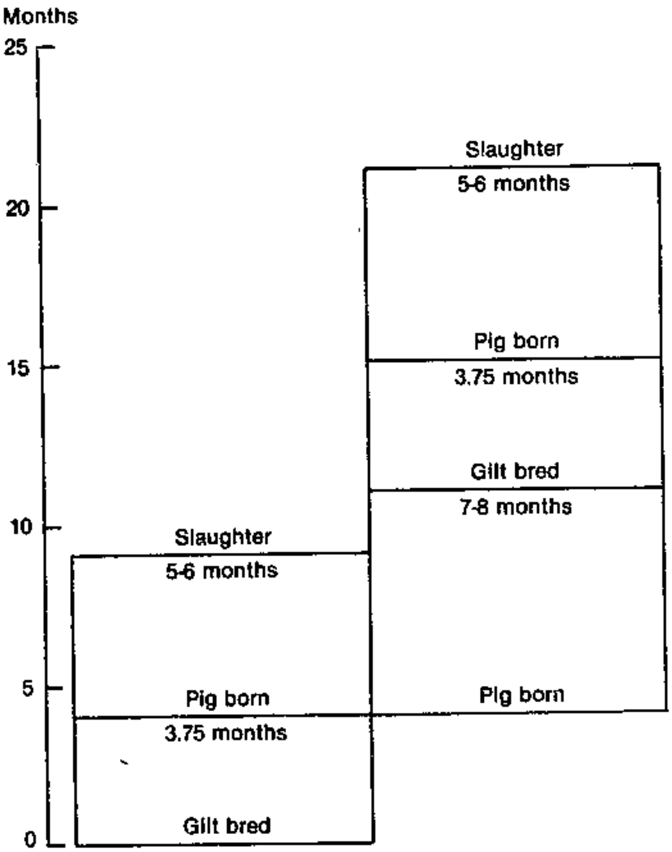
Biological lags in the beef production process



Sources: (5, 17).

Figure 2

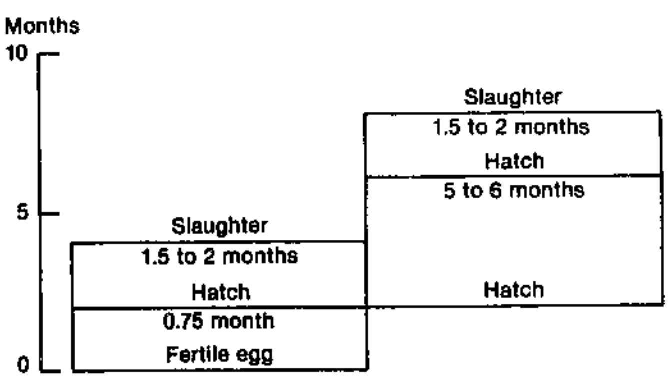
Biological lags in the pork production process



Source: (12).

Figure 3

Biological lags in the chicken production process



Source: (14).

The model is separated into three primary production sections for cattle, hogs, and poultry, a consumption or net disappearance section, and a price determination section (figs. 4-7). Each of the primary production sections is assumed to be a separate entity and is solved independently of the others. The basis for this specification lies in two basic assumptions. First, resource allocations and physical production plants within the meat complex are very rigid in the short run. Technological advancements in animal production have created a situation where efficient physical production plants, such as feedlots, hog confinement facilities, and broiler hatcheries and houses are highly specialized and specifically designed for one type of animal. Because of this producer specialization, moving from one animal type production to another is costly and time consuming because new production facilities must be built.

Input costs such as feed prices are historically affected more at the margin by export demand because of the volatility of export demand than by additional expansion by the meat animal production process. Therefore, increases at the margin in animal production usually have little impact on average livestock production costs. The limited scope of this model also precluded the incorporation of a feed sector, and feed prices are assumed exogenous, which eliminates most interaction with crop producers. Animal producers also compete for another variable input: operating capital. Because animal producers are competing with all other sectors of the economy, however, the effect of animal producers on the cost of money is minute at the margin.

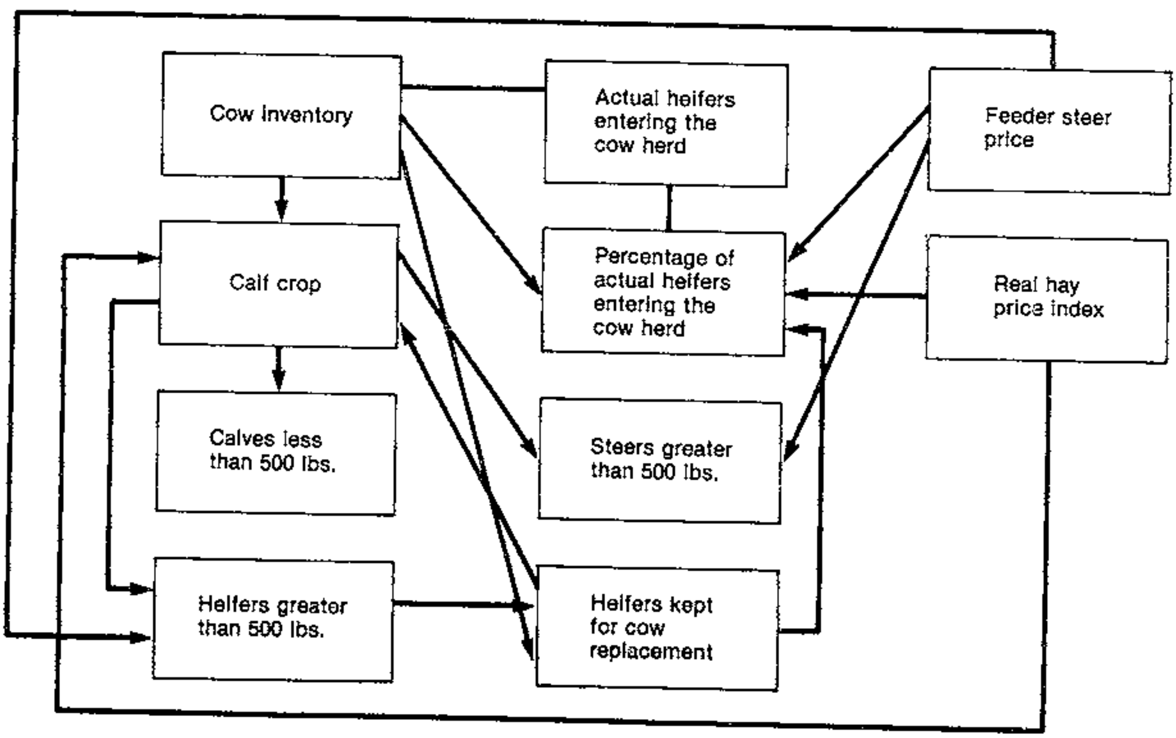
Output from the primary production section is in the form of a carcass-weight product estimate. Consumption is then derived from this production estimate as a residual. This methodology is the same as that used to derivate consumption data reported by USDA. Within the consumption section of the model, cold storage stocks and production are the only endogenously determined values. Foreign trade, imports, exports, and shipments, along with military consumption, are assumed to be exogenous. Once the consumption estimates are determined by an identity, per capita values are determined by dividing total consumption by population.

The final link in the model structure is the price determination section (fig. 8). Meat supplies become very inelastic within a quarter. Large changes in the supplies of meat do not occur within a quarterly period. In periods of high prices, female animals are placed into breeding stocks and removed from slaughter stocks, reducing supplies in the short run. Producers also tend to market slaughter animals faster during such periods, but at lighter weights. Price gains within a period thus tend to decrease production at the margin. Inversely, price reductions tend to increase production in the short run because fewer animals are retained for breeding, and feeders tend to hold animals longer (with resulting weight gains), speculating on price increases. Variation because of these factors, however, is small on a quarterly basis when compared with total supplies. More importantly, premiums are paid for specific weights and grades of animals. The ranges for these weight and grade standards are fairly narrow, behooving the producer to remain within the standards. Lastly, the ability to hold either the animal or meat in storage becomes cost restrictive. Live animals cannot be kept in "storage" because of the cost of feeding them and the price reduction that producers receive if they hold the animals beyond a certain weight, yield, and quality grade. Meat cannot be held for an extended time because it is highly perishable. Shelf life for meat is very short if it is not processed or frozen, and about 2-3 weeks if refrigerated. Further processing or freezing of meat is only done to the low-valued cuts, except for some poultry and pork products. High-valued cuts are discounted if frozen or processed.

Meat supplies are relatively invariant within a quarter and interquarter movement of meat is very small (that is, delaying marketing of the meat or the animal into another quarter). Given the perishability of the product, meat supplies and consumption within a quarter are assumed to be highly inelastic. Price adjustment clears the market and ensures that all that is produced is consumed. The producer and the consumer are assumed to be price takers because of the individual's inability to affect the market. Marketing agents who transform the live animal to the edible meat product also adjust prices until consumers purchase all available supplies. Knowing the price that is presently clearing the market and their own cost of transforming

Figure 4

Annual cattle production section



the live animal into the edible meat product, marketing agents can then adjust their bids for live animals.

Finally, producers use information about current prices and costs of production to form the expectations on which they base the production decisions.

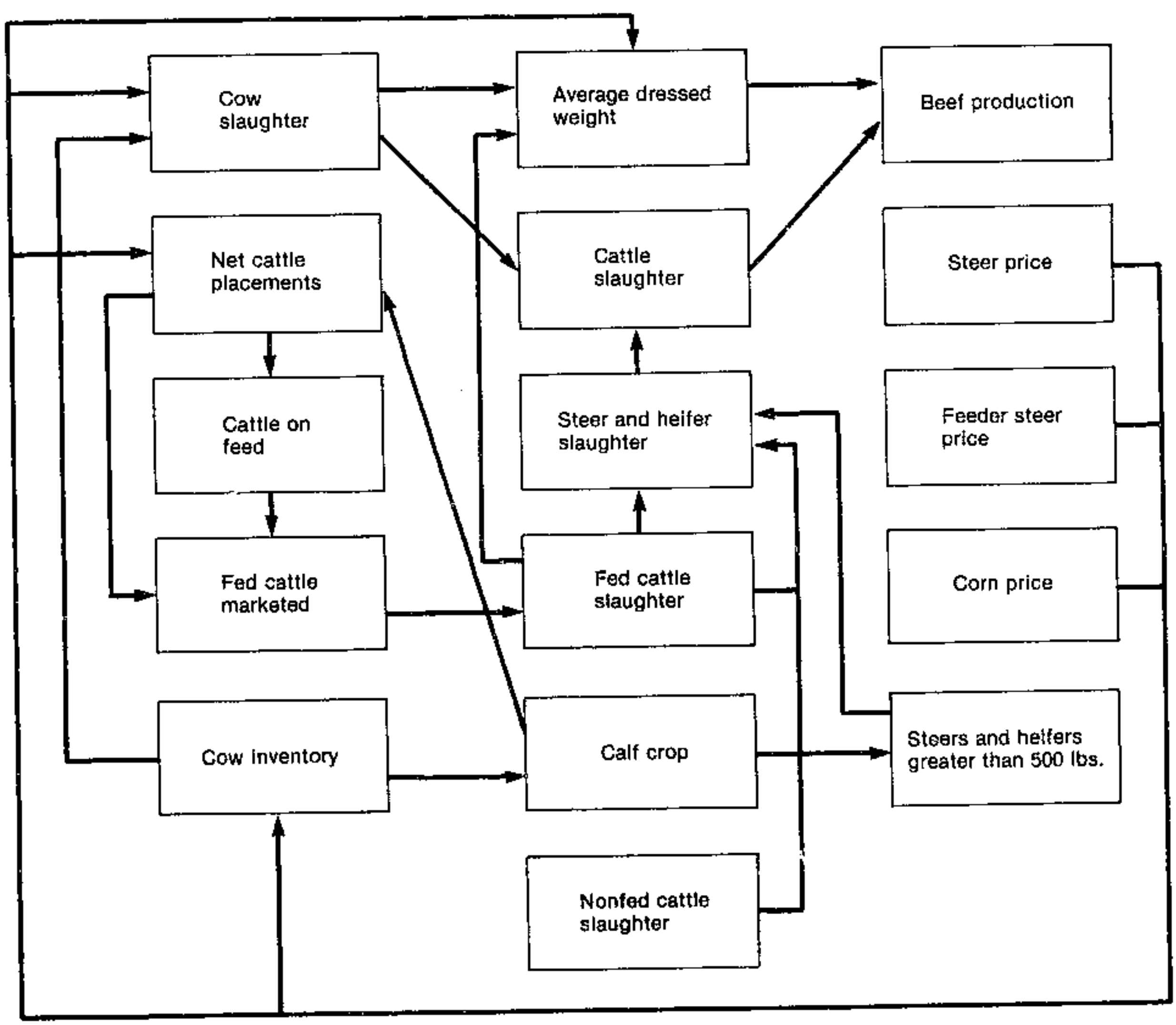
Model Specification

An ordinary least squares (OLS) estimator methodology is used to estimate the equations under a recursive model structure. Data used in the model estimation are from USDA sources and span 1955-81 for annual equations and 1970-81 for quarterly equations. Choices concerning the specific functional form of the equations are based on structural soundness and residual evaluation statistics, the latter presented in the model evaluation section at the end of this report.

Results presented here are in the logical order of the model. Each equation presents either a physical relationship that replicates the transformation of the product over time, and/or a behavioral relationship

Figure 5

Quarterly cattle production section



which represents the decisionmaking process of the industry. The initial sections of the model deal with the primary production sectors. Consumption and price equations are presented in the final two sections.

Each of the primary production sections is a separate block of equations. The output from these primary production sections feeds into the consumption and price determination sections. Cattle production is broken into annual and quarterly sections. Hog and broiler production consist of quarterly equations.

Cattle Equations

Length of time involved in the actual production process is important when analyzing the cattle industry. Cattle production is measured in years. Any reaction by the producers involves a long time lag before the realization of the decision's outcome. One must also note that the cattle sector is composed of two separate production processes; cow-calf operators and cattle feeders are usually separate entities. Because of this, the cattle equations include an annual capital stock section which feeds into the equations representing beef production.

Figure 6

Hog production section

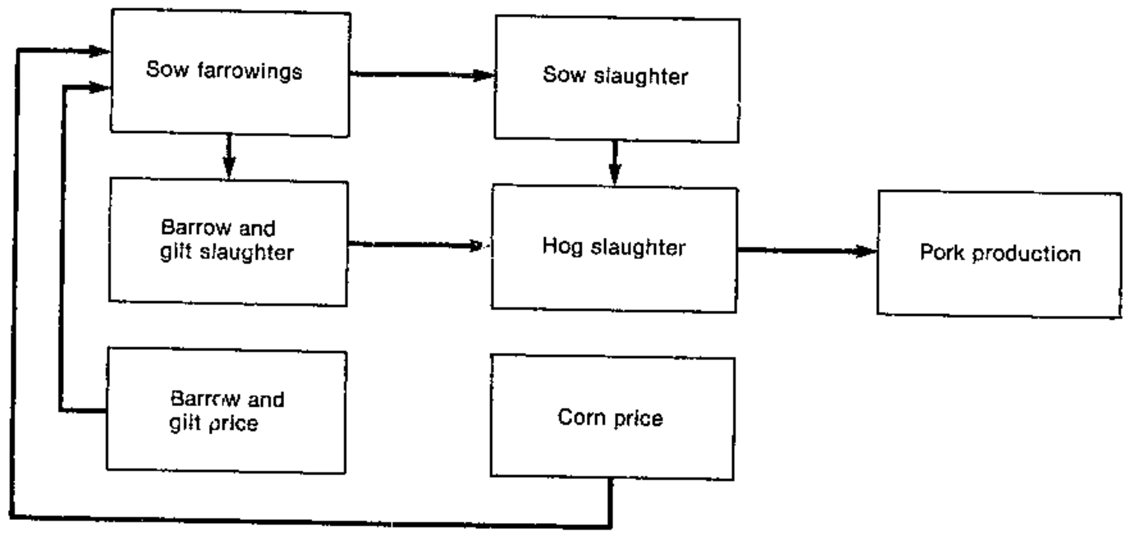
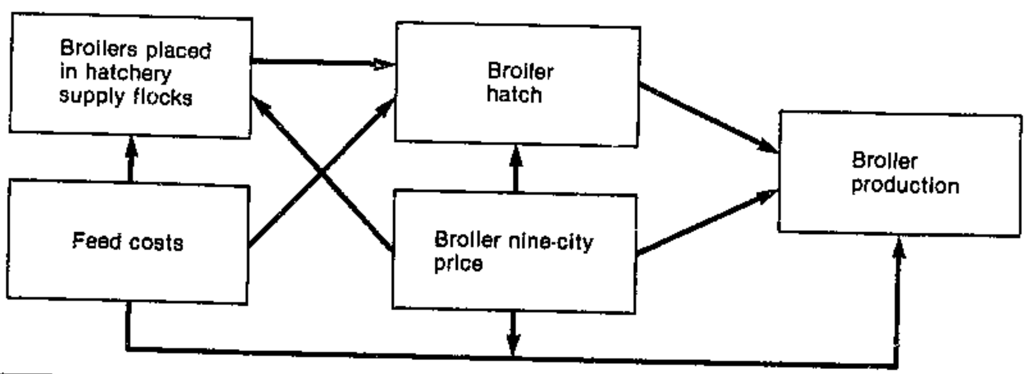


Figure 7

Broiler production section



Cow-calf operators produce two separate products. First, they provide the raw material for the cattle feeding and slaughtering industry. They produce calves which are sold, after reaching a given size, either to slaughter facilities or to individuals who wish to put further weight on the animals. Second, they provide cows for the slaughter industry as a byproduct of the calf-producing operation. Cow meat is usually used in processed meats and is not valued as highly as fed beef.

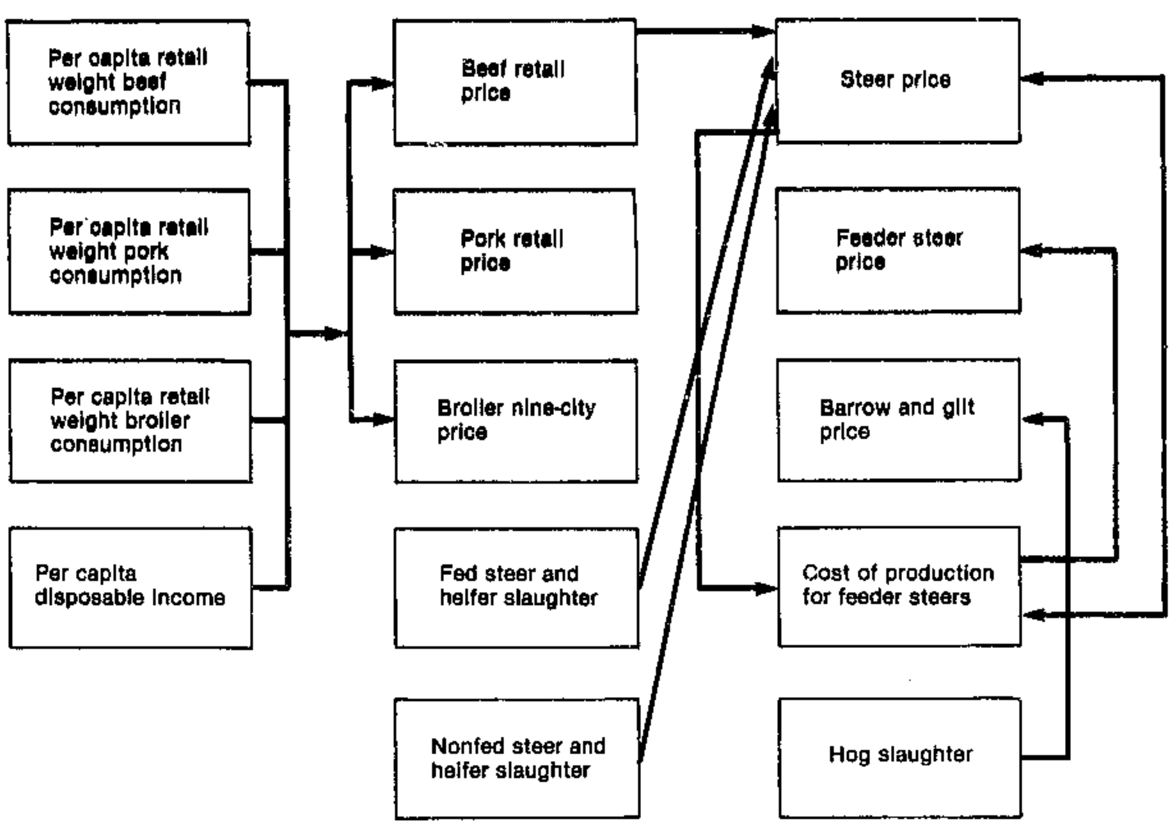
Cattle feeding is the major U.S. meat-producing industry. The output of this industry is a high-quality, high-value live animal used to produce fresh, table-ready cuts of quality meat and except for byproducts, is seldom processed further. Producers use feeds and calves as the raw materials to attain the finished product. Cattle feeders, therefore, are the major users of the cow-calf operator's primary product. Decisions made by feedlot operators affect the cow-calf subsector and hence the behavior of the industry through prices paid for calves.

Cow Inventory on Farms January 1. Any production-based model starts with identifying the capital base from which production can be derived. Cows on farms January 1 represent the principal constraint on the production of raw materials (calves) for beef production. The equation for January 1 cow numbers is an identity. Current year cow numbers are simply the number on farms at the beginning of last year, minus cow slaughter and death losses, plus heifers entering the cow herd during the previous year.

Cow inventory (L) = (1)
Cow inventory (L–1)
– death loss (L–1)
– annual cow slaughter (L–1)
+ heifers entering the cow herd (L–1)

Figure 8

Retail-farm price determination section



Behavioral equations which represent cow slaughter and the actual heifers entering the cow herd in the model are described below. Death loss is set at 2 percent of the cow herd, typical of past years. This value varies according to climatic condition in the individual production regions. The costs of obtaining adequate regional climatic information, however, compared to the benefit this information provides, is not sufficient to justify its inclusion.

Heifers, Steers, and Bulls Less Than 500 Pounds. Heifers, steers, and bulls less than 500 pounds on farms January 1 are animals born late the previous year. On the average, animals in this category account for 66.4 percent of the previous year's calf crop. This value varies less than 3 percent. Without specific knowledge of the dates of calving and various growth factors, forecasting this variable becomes difficult. A fixed factor of 66.4 percent of the calf crop was thus used to forecast this value.

Steers Greater Than 500 Pounds on January 1. Steers greater than 500 pounds represent the stock of male animals available for placement in the feedlot or used for slaughter. Steers make up the majority—about two-thirds—of cattle placed in feedlots. Steers greater than 500 pounds on farms were assumed to be a function of the calf crop in the previous year and the annual average steer price (table 1).

Steers greater than 500 pounds (L) = (2)
A [calf crop (L–1),
annual feeder steer price (L–1)][1]

Calf crop lagged 1 year represents the inventory of animals that could pass into this cateogry. One would expect the coefficient on this variable to be less than 0.5, a) because 50 percent of the calf crop are male and b) because 70 percent of the calves are born in the first half of the year, so that a large amount of these could reach 500 pounds by January 1 (fig. 1). Since 64 percent of the previous year's calf crop is less than 500 pounds, one would expect that about 18 percent of the calf crop would be male and reach 500 pounds or more by the next year. The percentage of the steers greater than 500 pounds would be affected by death loss and nonfed slaughter. These factors could cause some variation in this coefficient.

Average feeder steer price during the previous year is included to reflect the profitability of holding the animal instead of slaughtering it. As feeder steer prices rise, the demand for feeder animals is assumed to increase. Hence, a large percentage of the steers should be placed in feedlots, reducing the percentage of steers from the previous year's calf crop slaughtered at less than 500 pounds.

Heifers Greater Than 500 Pounds. Heifers greater than 500 pounds on farms January 1 measures the number of heifers used for breeding, herd replacement, feedlot placement, or slaughter. This variable is assumed to have the same functional form as steers greater than 500 pounds because of the same growth relationships among the sexes. The number of heifers over 500 pounds is assumed to be a function of average annual feeder steer price and the previous year's calf crop.

Heifers greater than 500 pounds (L) = (3)
A [calf crop (L–1),
annual feeder steer price (L–1)]

The calf crop during the previous year represents the stock of animals available to enter the heavier than 500 pounds category. Again, 50 percent of the calves born are assumed to be heifers and a proportion of those heifers born in the first half of the year will reach 500 pounds by January 1. The same problem arises, however, with death loss, nonfed slaughter, and inclusion of some late calves from 2 years earlier. Average feed r steer price was included to reflect the demand for calves. If the feeder steer price increases, more heifers are probably placed in the feedlot, precluding them from being slaughtered prior to reaching 500 pounds. Unlike steers, however, the heifers could be retained for breeding purposes. Increasing feeder steer prices may encourage the retention of replacement heifers and reduce the number of heifers slaughtered before they reach 500 pounds.

Heifers Greater Than 500 Pounds Kept for Cow Replacements. Heifers kept for cow replacement serve two purposes. First, the productive life of a cow is

[1]Stochastic equations are represented functionally with A( ) denoting an annual equation and Q( ) denoting a quarterly equation. Each variable is followed by a subscripting variable enclosed in parenthesis, indicating the temporal relationship between the dependent and independent variables. An (L) subscript indicates an annual variable and (I) indicates a quarterly variable. A subscript (I–1) would indicate a one-quarter lag on the variable.

Table 1—Annual cattle equations[1]

Dependent variable: Steers greater than 500 lbs.

SSE 5732278.0[2]	F ratio	46.443
DF 20	Probability-F	.0001
MSE 318460.0	R-square	.8377

Variable	Parameter estimate	Standard error	T ratio	Probability-T
Intercept	−939.830	1869.735	−0.503	0.6213
Annual feeder steer price (L−1)	29.084	7.713	3.771	.0014
Calf crop (L−1)	.340	.042	8.060	.0001

Dependent variable: Heifers greater than 500 lbs.

SSE 3928869.0	F ratio	42.641
DF 20	Probability-F	.0001
MSE 218270.0	R-square	.8257

Variable	Parameter estimate	Standard error	T ratio	Probability-T
Intercept	−3691.434	1547.926	2.385	.0283
Annual feeder steer price (L−1)	18.836	6.385	2.950	.0086
Calf crop (L−1)	.283	.035	8.089	.0001

Dependent variable: Heifers kept for cow replacements on farms Jan. 1

SSE 1539132.0	F rato	65.927
DF 20	Probability-F	.0001
MSE 85507.312	R-square	.8799

Variable	Parameter estimate	Standard error	T ratio	Probability-T
Intercept	819.818	1008.056	.813	.4267
Cow inventory (L)	.235	.021	11.224	.0001
Cow slaughter index (L−1)/3	−13301.454	2552.582	−5.211	.0001

Dependent variable: Calving rate

SSE 0.0036532	F ratio	18.498
DF 19	Probability-F	.0001
MSE .0001658	R-square	.7762

Variable	Parameter estimate	Standard error	T ratio	Probability-T
Intercept	0.789	0.095	8.279	0.0001
Heifers kept for cow replacement (L)/ cow inventory	1.006	.403	2.498	.0238
Change in the feeder steer price (L−1)	.001	.0005	2.498	.0156
Real hay price index (L−1)[4]	−.806	.018	−4.473	.0004

Continued—

Table 1—Annual cattle equations—continued

Dependent variable: Percentage of heifers entering the cow herd

	SSE 0.027784		F ratio	6.071
	DF 19		Probability-F	.0041
	MSE .017139		R-square	.6182

Variable	Parameter estimate	Standard error	T ratio	Probability-T
Intercept	.346	.159	2.171	.0464
Annual feeder steer price (L–1)	–.002	.001	–1.315	.2083
Squared annual feeder steer price (L–1)	.000066	.000019	3.538	.0030
Cow inventory index (L–1)	.536	.198	2.712	.0161
Real hay price index (L–1)	–.065	.068	–.957	.3538

[1](I) Denotes quarterly data, (L) denotes annual data, (I-n) denotes the nth period lag of the variable, Dn denotes the nth quarter intercept shifter, Dn preceding a variable name denotes a nth quarter slope shifter.

[2]SSE= sum of square error, DF= degrees of freedom, MSE= mean square error, F ratio= F test value, Probability-F= Significance level of the F-test, R-square= coefficient of determination.

[3]Cow slaughter index (L) = annual cow slaughter (L)/cow inventory(L).

[4]Real hay price index (L) = [(hay price(L)/GNP deflator (L))/(hay price(base)/GNP deflator(base)].

finite, so a certain percentage of the cow inventory must be replaced each year as a maintenance activity. Second, as producers react to profitable returns, they will keep more heifers in order to expand production. Heifers kept for cow replacement is assumed to be a function of the January 1 inventory of cows and the previous year's cow slaughter index.

Heifers greater than 500 pounds kept for cow replacement (L) = A [cow inventory (L), cow slaughter index (L–1)] (4)

The parameter on the cow inventory variable should reflect the depreciation rate of the cow inventory. The value of this variable ranges from 10 to 17 percent. An index of the cow slaughter to the cow inventory was used to reflect producers' decisions to expand or contract the herd. If the rate of cow slaughter increases as a percentage of cow inventory, producers are not expanding their herd and the quantity of heifers kept for cow replacement should decline.

Actual Heifers Entering the Cow Herd. Heifers actually entering the cow herd by definition is the number of heifers that calve and thus enter the cow herd. Heifers actually entering the cow herd is derived as a percentage of the number of heifers kept for cow replacement.

Actual heifers entering the cow herd (L) = Percentage of heifers entering the cow herd (L) × heifers kept for cow replacement (L) (5)

Percentage of Heifers Entering the Cow Herd. The value estimated is the percentage of heifers entering the cow herd (actual heifers entering the cow herd/heifers kept for cow replacement). Heifers entering the cow herd depend on several factors, both economic and climatic. This variable is thus assumed to be a function of a quadratic form of annual feeder steer prices, the real hay price index, and the level of cow inventory last year. The parameter values for the annual feeder steer prices are of indeterminate sign; however, the impact of an increase in the feeder steer price would keep a larger percentage of heifers at the margin. Impacts of the price change would be reflected in the producer's decision to keep a potential replacement heifer or sell her. Real hay price index reflects the capacity constraints on pasture and ranges; the production of hay and pasture are assumed to be affected by the same process. Real hay price increases are thus assumed to reflect a reduction of pasture-carrying capacity in relation to the cattle inventory (demand). Thus, hay price increases lead to fewer heifers retained to give birth and to a lower calving rate among heifers, due to a lessening of the nutrition base of the pastures.

Calf Crop. Calf crop is the number of calves born within a year. This equation represents a flow category, unlike the previous stock equations. Calf crop is assumed to be a function of the cow inventory.

Calf crop (L) = (6)
cow inventory (L) × calving ratio (L)

This equation estimates the calf crop as a percentage of the cow inventory where the calving ratio varies between 86 and 94 percent of the cow inventory. It is done with a behavioral equation approximating the factors which affect the number of calves born. Important factors in the calving ratio are the ratio of heifers kept for cow replacements to cow inventory numbers, the change in feeder steer prices, and the index of real hay prices.

Calving ratio (L) = (7)
A [(heifers kept for cow replacement (L)/cow inventory (L)), change in the feeder steer price (L−1), index of real hay price (L)]

A ratio of heifers kept for cow replacement to cow inventory reflects the number of first calf heifers that may calve during the year. Since the calving rate is the ratio of calf crop to cow inventory, the number of heifers that calve during the year is not included in the denominator, but their calves are included in the numerator. The calving rate then increases as the percentage of heifers to cows increases. The change in feeder steer prices picks up changes in breeder decisions about replacement heifers which may be removed before they calve. Real hay price index represents conditions affecting the cows' ability to calve. As the real hay price index increases, pressure is put on range capacity and the nutritional content of the pastures may decline, hindering the cows' calving ability. Poor nutrition may increase conception problems, cause an aborted fetus, or lower disease resistance.

Quarterly Cattle Equations. Quarterly equations define the production of beef, drawing from the stock of available raw materials. Both behavioral equations and identities are used. Behavioral equations represent both the physical production relationship and economic decision criteria. The important decision points in the quarterly cattle section are the cow slaughter equation and the cattle placement equation. Cow slaughter defines the future production of the cattle sector. Increases or declines in cow slaughter are akin to reduction or expansion in plant capacity in the manufacturing industry. Net cattle placements represent the producer's expectation of profitability and the amount of high-quality beef to be produced during the next few periods.

Cow Slaughter. Cow slaughter measures the reduction in the production capacity of the cattle industry. Cows represent a highly liquid production capital with a reasonably high salvage value. Cow slaughter is a result of two management practices: maintenance of the production capital and capacity utilization. Cow slaughter is assumed to be a function of the expected feeder steer price, the number of cows on farms January 1, and seasonal slope shifters (table 2).

Cow slaughter(I) = (8)
Q [expected feeder steer price (I), cow inventory (L), D1 × cow inventory (L), D2 × cow inventory (L), D3 × cow inventory (L)]

The cow-calf operator must form an expectation of future revenues for a product in deciding to maintain or reduce production capacity through cow slaughter. A distributed lag variable of feeder steer price is used to approximate the producer's expectations. As the producer's feeder steer price expectations increase, one would expect that the operator would reduce cow slaughter. A second management practice reflected in cow slaughter is maintaining the productivity of the cow herd. As in all production facilities, cow productivity declines after a certain age. A certain percentage of the cow herd needs to be replaced each year. Seasonal factors also affect the cow slaughter, such as low periods of milk production, calving, and breeding practices.

Net Cattle Placements in 13 States. Net cattle placements measure the number of feeder animals placed into feedlots. These animals are fed a growth ration until they reach a specific weight (about 1,050 pounds on average). Cattle placed on feedlots remain in the feedlots an average of 5-6 months (two quarters). Cattle placed are raw material input in the production of high-value beef. The decision to place feeder animals on feed is based on the expected profitability of the operation. Since the quarterly data period is shortrun in nature, the physical feeding facilities are considered a fixed cost. Therefore, only variable costs and the inventory of available raw material affect the producer's decision to place cattle. Cattle placements are assumed to be a function of expected steer price, expected feeder steer price, corn price, calf crop, and seasonal slope shifters.

Net cattle placements (I) = (9)
Q[(distributed lag steer price (I)/corn price (I-1)), distributed lag feeder steer price (I), D1 × calf crop (L-1), D2 × calf crop (L-1), D3 × calf crop (L-1), D4 × calf crop (L)]

Table 2—Quarterly cattle equations

Dependent variable: Cow slaughter

SSE	7246184		F ratio	178.54
DF	38		Probability-F	.0001
MSE	190689		R-square	.9592

Variable	Parameter estimate	Standard error	T ratio	Probability-T
Distributed lag feeder steer price (I)[1]	12.957	3.572	-3.6277	0.0008
Cow inventory (L)	.054	.004	12.4186	.0001
D1Cow inventory (L)	-.005	.004	-1.2666	.2130
D2Cow inventory (L)	-.007	.004	-1.8893	.0665
D3Cow inventory (L)	-.004	.004	-1.1596	.2534

Dependent variable: Net cattle placements

SSE	1859582		F ratio	436.06
DF	37		Probability-F	.0001
MSE	502502.2		R-square	.9861

Variable	Parameter estimate	Standard error	T ratio	Probability-T
Steer price (I-1)/corn price (I-1)	111.120	20.424	5.4408	.0001
Distributed lag feeder steer price(I)	-7.348	6.588	-1.1154	.2719
D1Calf crop (L-1)	.093	.013	6.9211	.0001
D2Calf crop (L-1)	.101	.013	7.7048	.0001
D3Calf crop (L-1)	.097	.014	7.1572	.0001
D4Calf crop (L)	.137	.014	9.7078	.0001

Dependent variable: Fed cattle marketings

SSE	5084482		F ratio	3416.30
DF	40		Probability-F	.0001
MSE	127112.1		R-square	.9961

Variable	Parameter estimate	Standard error	T ratio	Probability-T
Total cattle on feed(I)[2]	.354	.0050	70.7627	.0001
D2Total cattle on feed(I)	.007	.0090	.8015	.4276
D3Total cattle on feed(I)	.023	.0086	2.6191	.0124

See footnotes at end of table.

Continued—

Since the decision to place cattle is made several periods before realization of the final product, the producer must form expectations as to the costs and returns of the feeding process. A three-quarter weighted distributed lag is used to represent the feeder's expectation of steer prices because past price behavior is assumed to be a part of the producer's expectations (table 2). A ratio of steer prices to corn price is used to measure the profitability of the feeding function. The producer can then determine if the feeder steer price allows for a profit.

Cattle on Feed in 13 States. Cattle on feed at the beginning of the quarter is a stock measure of the

Table 2—Quarterly cattle equations—continued

Dependent variable: Fed cattle slaughter

	SSE 368074.7		F ratio	45567.25
	DF 38		Probability-F	.0001
	MSE 9437.814		R-square	.9998

Variable	Parameter estimate	Standard error	T ratio	Probability-T
Fed cattle marketings(l)	1.137	0.005	220.6599	.0001
D1Fed cattle marketings(l)	.009	.008	1.1313	.2649
D2Fed cattle marketings(l)	.021	.008	2.7939	.0080
D3Fed cattle marketings(l)	.011	.007	1.5453	.1304

Dependent variable: Commercial steer and heifer slaughter

	SSE 4920156		F ratio	5.727
	DF 41		Probability-F	.0023
	MSE 120004.8		R-square	.2953

Variable	Parameter estimate	Standard error	T ratio	Probability-T
Intercept	5545.034	1438.376	3.855	.0004
Corn price(l)	119.005	107.895	1.1030	.2765
Distributed lag steer price(l)[3]	− 17.001	5.582	− 3.045	.0041
Steers and heifers greater than 500 lbs. (L−1)	.129	.087	1.486	.1449

Dependent variable: Average dressed weight of cattle

	SSE 6028.916		F ratio	22.41
	DF 38		Probability-F	.0001
	MSE 154.587595		R-square	.6329

Variable	Parameter estimate	Standard error	T ratio	Probability-T
Intercept	540.695	12.269	44.0717	.0001
Steer price (l−1)	.432	.210	2.0520	.0469
Corn price (l−1)	9.757	4.822	2.0235	.0499
Ratio of fed to nonfed slaughter(l)	15.625	2.706	5.7743	.0001

[1]Distributed lag feeder steer price(l) = (3(feeder steer price (l−1) + 2(feeder steer price (l−2)) + (feeder steer price (l−3)))/6.
[2]Total cattle on feed(l) = cattle on feed(l) + net cattle placements(l).
[3]Distributed lag steer price(l) = (3(steer priced (l−1)) + 2(steer price (l−2)) + (steer price (l−3)))/6.

number of cattle fed. This variable represents the queue of animals in the production process. Cattle on feed is an identity—cattle on feed in the previous quarter minus the number marketed during that quarter, plus the number of cattle placed during the previous quarter.

Cattle on feed (I) = (10)
Cattle on feed (I–1)
– fed cattle marketed (I–1)
+ net cattle placements (I–1)

Total Cattle on Feed. Total cattle on feed during a quarter represents the stock from which fed cattle marketings are drawn. Total cattle on feed is an identity equation which includes the number of cattle on feed at the beginning of the quarter and the number of cattle placed during the quarter.

Total cattle on feed (I) = (11)
cattle on feed (I)
+ net cattle placements (I)

Fed Cattle Marketings in 13 States. Fed cattle marketings are the number of fed animals sold to packers during a quarter by producers in the 13 reporting States. The number of fed cattle marketed depends on the number of cattle on feed, their weight, and seasonal factors. Since information on placement weights and cattle on feed weights is not available within the model, only onfeed numbers and seasonal slope shifters are included. Placement weight data would allow the model to track the movement of cattle through feedlots better. Fed cattle marketing is estimated as a percentage of total cattle on feed, that is, cattle on feed at the beginning of the quarter plus placements during the quarter.

Fed cattle marketed (I) = (12)
Q [total cattle on feed (I),
D2 × total cattle on feed (I),
D3 × total cattle on feed (I)]

Variation in the number of feedlot cattle marketings during a quarter depends on several factors: weather, the number of cattle placed, the weight of cattle placed in the previous quarters, and the weights at which these cattle are marketed. Most of this information is beyond the scope of this model, so that seasonal slope shifters are used. The slope shifters incorporate some weather variation. Total cattle on feed represents the total number of animals available for marketing.

Commercial Steer and Heifer Slaughter. Commercial steer and heifer slaughter is broken down into two components, fed and nonfed slaughter. Fed steer and heifer slaughter is estimated by the U.S. Department of Agriculture (USDA) from the fed cattle marketed data, using a January 1 estimate of cattle on feed. Nonfed steer and heifer slaughter is residually derived as the difference between fed steer and heifer slaughter and commercial steer and heifer slaughter reported by the Statistical Reporting Service (SRS), USDA. As a residual value, nonfed slaughter contains all the measurement errors within the estimates of the other slaughter classifications. Estimating a residual value becomes very difficult. Examining the mean and the standard deviation is done using the coefficient of variation (standard deviation/mean), illustrating the large variation within the nonfed steer and heifer slaughter data. Commercial steer and heifer slaughter has a coefficient of variation of 5.44 percent; fed steer and heifer slaughter has a coefficient of variation of 7.82 percent. However, the coefficient of variation for nonfed steer and heifer slaughter is 61.20 percent. This inherent error within the nonfed slaughter data exists in part because nonfed slaughter is a residual number, and thus contains errors from all the survey data in the commercial cattle slaughter and fed slaughter estimates. Nonfed slaughter is derived as a residual number within the model framework by the same process that it is estimated by the data source, USDA.

Fed cattle marketings data are survey data for 13 States. However, fed cattle slaughter data are derived from the 13 States' marketings, representing the U.S. total within the model framework. Fed cattle slaughter is estimated using an expansion factor which is seasonally adjusted for the second and third quarters.

Before the number of quarterly reporting States was reduced from 23 to 13, fed cattle slaughter was derived by expanding the total number of U.S. cattle on feed on January 1, then dividing by the number of cattle on feed January 1 in the 23 States. This ratio varied from about 1.04 to 1.05. However, when the number of reporting States was reduced to 13, this expansion factor increased to about 1.15. The information contained in the cattle on feed report was reduced by about 10 percent. Problems arise in using this ratio because the seasonal and cyclical variation in the 10 States no longer reporting was much greater than for the 13 reporting States.

To circumvent the seasonal-cyclical factors affecting the fed cattle expansion factor, the actual expansion factor is estimated as a function of the calf crop. Seasonal slope shifters incorporate the seasonal-cyclical impacts on the expansion factor. The estimated expansion factor is then used to expand the 13-State estimate up to the U.S. total.

Fed steer and heifer slaughter expansion factors (I) = (13)
Q [calf crop (L–1),
D1 × calf crop (L–1),
D2 × calf crop (L–1),
D3 × calf crop (L–1)]

Commercial steer and heifer slaughter is the total number of fed and nonfed steers and heifers slaughtered during a quarter. This assumes that steers and heifers make up the same proportion of commercial slaughter as of slaughter under Federal inspection. Again, commercial steer and heifer slaughter is a function of steer prices, corn prices, and the steers and heifers heavier than 500 pounds January 1.

Commercial steer and heifer slaughter (I) = (14)
Q [steer price (I–1), corn price (I–1),
steers and heifers heavier than 500 pounds (L)]

The impact of fed steer prices on quarterly commercial slaughter of steers and heifers should be negative, reflecting the feeder's propensity to increase placements, thus delaying slaughter in the short term with the expectations of higher returns. Corn prices, a major cost to feeders, will tend to discourage placements as they rise, increasing near term slaughter. The number of steers and heifers greater than 500 pounds January 1 indicates the supply of cattle available for slaughter.

Nonfed Steer and Heifer Slaughter. Nonfed steer and heifer slaughter is simply the difference between fed steer and heifer slaughter and the commercial steer and heifer slaughter.

Nonfed steer and heifer slaughter (I) = (15)
commercial steer and heifer slaughter (I)
– fed steer and heifer slaughter (I)

Cattle Slaughter. Cattle slaughter is an identity equation which includes the various categories of cattle slaughter. Bull slaughter is not explicitly estimated in the model. Assuming that bulls are maintained at a ratio of slightly more than 1 to 20 cows in the breeding herd, bull slaughter is set at 6.5 percent of the cow slaughter.

Cattle slaughter (I) = (16)
cow slaughter (I) × 1.065 + commercial steer and heifer slaughter (I)

Average Dressed Weight for Cattle. Average dressed weight for cattle is the mean eviscerated carcass weight of cattle. The average weight tends to vary with the ratio of steers and heifers to cows slaughtered, steer prices, and feed prices. Steers and heifers dress out at heavier weights than cows, averaging about 690 pounds for steers and 580 pounds for heifers, compared with about 500 pounds for cows. As the ratio of steers and heifers to cows increases, the average slaughter weight of cattle would be expected to increase. Steer prices represent the marginal revenue of additional weight gain added by the feedlot, and corn represents the marginal costs.

Average dressed weight (I) = (17)
Q [commercial steer and heifer slaughter (I)/cow slaughter (I), steer price (I–1), corn price (I–1)]

Beef Production. Beef production is the total amount of commercially produced U.S. beef during a quarter on a carcass weight basis. It is an identity defined as average slaughter weight times cattle slaughter.

Beef production (I) = (18)
cattle slaughter (I) × average dressed weight (I)

Beef production is the final output of the cattle production section of the model and feeds into the consumption and price determination model section.

Hog Equations

The hog production section of the model consists of six quarterly equations. Initial inventory equations are not used because of the length of the production process (see fig. 2). Hog production takes about 9 months from the breeding of the sow to the slaughter of the barrow or gilt. Physiologically, a sow can farrow twice a year. Gestation lasts just under 4 months, and feeding usually lasts 5-6 months. Intrayear adjustments within the breeding herd can thus affect farrowings in the same year.

About 75-80 percent of hog producers have farrow-to-finish operations. Unlike the cattle industry, hog producers maintain both the breeding herd and the feeding operations. Hog production has become increasingly sophisticated. Hogs are kept inside a confinement building for their whole lives. Investment in building and equipment by hog producers was fairly heavy during the early and midseventies, giving the industry a high fixed cost component. Hog production is also often associated with crop production in mix enterprise farms, and is used as an alternative method of marketing corn.

Sow Farrowings. Sow farrowings are the number of sows giving birth during a quarter. Because intrayear adjustments in the breeding herd can be realized, annual stock numbers do not play a statistically significant role in forecasting sow farrowings. Sow farrowings are forecast using a partial adjustment functional form. Since sow farrowings are seasonal and there are no statistically useful data measuring a quarterly hog breeding stock, lags of one, four, and five quarters are used in the equation. Expected barrow and gilt prices and corn prices are also assumed to affect the number of sows farrowing (table 3).

Sow farrowings (I) = (19)
Q [expected barrow and gilt price (I),
corn price (I–1),
sows farrowing (I–1),
sows farrowing (I–4),
sows farrowing (I–5)]

The production process expands beyond a single time period as for cattle production. The producer must form expectations at the time of breeding as to the price received for the barrows and gilts. A distributed lag variable approximates the expected returns from the production process. Since hog producers incorporate both the breeding and feeding activity, they must incorporate the costs of feeding the animals into their decisionmaking process. The price of corn during the previous period represents the feeding cost facing hog producers. Because of the high fixed costs involved in a large part of the industry, producers use specialized facilities to full capacity, all other things constant, to maintain a certain percentage of use. The one-, four-, and five-quarter lag variables thus represent this adjustment process. One- and five-quarter lags pick up any trend in production. If the one-quarter lag is significantly greater than the five-quarter lag, then producers are probably expanding. A four-quarter lag indicates seasonal capacity use.

Pig Crop. Pig crop is the number of pigs born in a quarter. It is the product of sows farrowing and the number of pigs saved per litter. In this model the number of pigs saved per litter was assumed to be 7.3.

Barrow and Gilt Slaughter. Barrow and gilt slaughter averages about 95 percent of the total hog slaughter. These animals are usually marketed at about 5-6 months of age and weigh 180-240 pounds. Barrows and gilts are drawn from the pig crop of the previous two quarters. Seasonal intercept shifters are also used for the first and second quarters.

Barrow and gilt slaughter (I) = (20)
Q [pig crop (I–1), pig crop (I–2), D1 (I), D2 (I)]

Physical rate of growth to an optimal slaughter weight for hogs usually requires marketing the hogs at around 5–6 months of age. The pig crops from the two previous quarters represent the number of hogs available for slaughter. Coefficients on these variables should be larger in the two-period lag than in the one-period lag to reflect the time constraints on growth. Seasonal intercept shifters are included to account for seasonal differences in the growth patterns.

Sow Slaughter. Sow slaughter measures the maintenance of the breeding herd and marginal adjustments to the shortrun production capacity. The equation is structured to reflect adjustments in breeding herd productivity and adjustments due to profitability. Sow slaughter is assumed to be a function of sow farrowing during the previous quarter, the expected barrow and gilt price, the corn price, and seasonal intercept shifters.

Table 3—Pork equations

Dependent variable: Sow farrowings

SSE	349469	F ratio	48.110
DF	30	Probability-F	.0001
MSE	13978.748	R-square	.9059

Variable	Parameter estimate	Standard error	T ratio	Probability-T
Intercept	– 650.807	369.897	– 1.759	0.0907
Distributed lag barrow and gilt price	20.814	4.495	4.631	.0001
Corn price (I–1)	– 93.856	57.979	– 1.619	.1180
Sow farrowings:				
I–1	.664	.094	7.090	.0001
I–4	.883	.065	13.508	.0001
I–5	– .548	.098	– 5.656	.0001

Dependent variable: Sow slaughter

SSE	318257.0	F ratio	22.18
DF	30	Probability-F	.0001
MSE	12240.669	R-square	.8366

Variable	Parameter estimate	Standard error	T ratio	Probability-T
Intercept	500.771	309.969	1.616	.1183
Sow farrowing (I-1)	.525	.066	7.902	.0001
Distributed lag and barrow and gilt price	– 18.507	4.002	– 4.625	.0001
Corn price (I–1)	135.559	50.573	2.680	.0126
D1	– 229.546	55.606	– 4.128	.0003
D2	– 76.876	56.080	– 1.371	.1822
D3	– 244.582	55.158	– 4.434	.0001

Dependent variable: Barrow and gilt slaughter

SSE	45810415	F ratio	2037.97
DF	34	Probability-F	.0001
MSE	1527014.0	R-square	.8543

Variable	Parameter estimate	Standard error	T ratio	Probability-T
Intercept	500.771	309.969	1.616	.1183
Pig crop (I–1)	.342	.066	5.210	.0001
Pig crop (I–2)	.767	.067	11.384	.0001
D1	716.230	538.032	1.331	.1932
D2	968.796	560.748	1.728	.0943

[1]Distributed lag barrow and gilt price(I) – (3(barrow and gilt price (I–1)) + 2(barrow and gilt price (I–2)) + (barrow and gilt price (I–2)))/6.

Sow slaughter (I) = (21)
Q [sow farrowings (I–1), expected barrow and gilt price (I), corn price (I),
D1 (I),
D2 (I),
D3 (I)]

A one-period lag of sow farrowings is used, assuming that sows are culled after they have weaned their pigs (6-8 weeks). Expected barrow and gilt prices and the corn price represent the expected profitability of the feeding operation and should thus reflect the variables used by hog producers in their decisionmaking process.

Hog Slaughter. Hog slaughter includes various types of slaughter hogs. Boar slaughter is not estimated by a stochastic equation because it is usually less than 1 percent of total hog slaughter. A mean value of the historical ratio of boar slaughter to sow slaughter is used to estimate boar slaughter. Hog slaughter is defined as the sum of barrow and gilt slaughter plus sow slaughter times one, plus the boar slaughter percentage.

Hog slaughter (I) = (22)
Sow slaughter (I)
+ boar slaughter (I)
+ barrow and gilt slaughter (I)

Pork Production. Pork production is an identity equation which converts the number of head slaughtered to total carcass weight production. Pork production is simply the product of total hog production and average carcass weight.

Pork production (I) = (23)
hog slaughter(I) × 172.00

Broiler Equations

Poultry production is the fastest growing area within the meat complex. Gains are mainly due to improved efficiency in production, which lowers per-unit production costs. Efficiency gains allow producers to maintain increasingly lower prices relative to other meat products.

The poultry production sector structurally consists of three equations for broilers. Poultry production is a vertically integrated industry; therefore, decisions throughout the production process are made by the same entity. Poultry producers thus have greater control over their supply of raw materials and production capacity than the other industries of this model. Poultry producers make their decisions based on the overall production picture, breeding stock, feeding, and processing, unlike beef and pork production where these activities are not totally integrated.

Broiler Pullets Placements. Broiler pullets placements measure the additions to the inventory of breeding flock. These birds lay the eggs from which broilers are hatched. A capital stocks partial adjustment equation specification is used to develop the functional forms for hatchery supply flocks because the broiler industry is seasonal in production. A lag of four quarters was used for the partial adjustment variable for the breeding flock. Broiler placements were also assumed to be a function of feed costs, broiler prices, seasonal intercept shifter, and time trend (table 4).

Broiler pullets placed in hatchery supply flocks (I) = (24)
Q [broiler pullets placed in hatchery supply locks (I-4),
feed costs (I),
nine-city broiler price (I),
D1 (I),
D2 (I),
D3 (I),
time (I)]

The nine-city broiler price measures returns to producers. This price was replaced in 1983 by a 12-city price; for a comparison between these two prices, see (*7*).[2] Feed costs are estimated using a standard 70/30 percentage mix of corn to soybean meal in the ration and an efficiency factor calculated from industry data (see app. A). A four-period lag value of the dependent variable is incorporated to pick up adjustments in the capital stocks (pullets in supply flocks), which are seasonal. The time trend variable indicates increasing placements of broilers over time, due in large part to gains in efficiency and resulting lower prices to consumers, which in turn increase broiler consumption.

[2] Italicized numbers in parentheses refer to items in the references.

Table 4—Broiler equations

Dependent variable: Broilers placed in hatchery supply flocks

SSE 13888479	F ratio	27.94
DF 37	Probability-F	0.0001
MSE 375364.3	R-square	.7906

Variable	Parameter estimate	Standard error	T ratio	Probability-T
Intercept	−491647.0	122162.4	−4.0245	0.0003
Broilers placed in hatchery supply flocks (I−4)	.462	.105	4.3862	.0001
Broiler feed cost (I−2)	−9.720	2.817	−3.4502	.0014
9-city broiler price (I−2)	59.899	29.194	2.0518	.0473
D2(I)	547.787	233.364	2.3473	.0244
Time(I)	251.065	62.472	4.0189	.0003

Dependent variable: Broiler hatch

SSE 96653348663	F ratio	45.99
DF 37	Probability-F	.0001
MSE 2612252667	R-square	.8614

Variable	Parameter estimate	Standard error	T ratio	Probability-T
Intercept	−53035729.	10902068.	−4.8647	.0001
Weighted broilers placed in hatchery supply flocks(I−2)[1]	20.09	4.511	4.4532	.0001
9-city broiler price (I−1)	3247.692	2430.262	1.3364	.1896
Broiler feed cost (I−1)	−427.661	234.66C	−1.8224	.0765
D2(I)	52877.56	18603.05	2.8430	.0072
Time(I)	27062.97	5581.935	4.8483	.0001

Dependent variable: Broiler production

SSE 184525520445	F ratio	68.49
DF 40	Probability-F	.0001
MSE 80228848715	R-square	.9582

Variable	Parameter estimate	Standard error	T ratio	Probability-T
Intercept	−84305.40	76641.27	−1.10	.2765
Broiler hatch (I−1)	2.351	.148	15.5441	.0001
9-city broiler price (I−1)	3831.722	1665.962	2.3064	.03
Broiler feed cost (I−1)	−117.961	84.86	−1.39	.2230
D2(I)	94260.37	18446.25	5.11	.0001
D3(I)	122349.7	17251.6	7.09	.0001
D4(I)	−61663.96	25909.22	2.3830	.0300
Time(I)	7110.86	1896.23	3.75	.0004

[1]Weighted broilers placed in hatchery supply flocks (I) = broilers placed in hatchery supply flocks (I)+0.80 (broilers placed in hatchery supply flocks (I-1)+0.61 (broilers placed in hatchery supply flocks (I-2)

Broiler Hatch. Broiler hatch is the number of broiler chicks hatched during a quarter. This equation represents producer decision about production levels. The broiler industry tends to have excess amounts of broiler hatching eggs at any point in time. Excess hatching egg production easily allows producers to expand broiler production at the margin. Incubation periods are sufficiently short that decisions can be made during the quarter which can affect the hatch during that quarter. Broiler hatch is a function of weighted broiler type pullets placed, wholesale broiler price, feed costs, seasonal intercept shifters, and a time trend variable.

Broiler hatch (I) = (25)
Q [weighted broilers placements (I)[3]
feed costs (I), nine-city broiler price (I–1),
D1 (I),
D2 (I),
D3 (I),
time (I)]

Weighted broiler placements indicate broiler egg production capability. The equation indicates that each broiler hen hatches about 20 eggs during the quarter. At the margin, hatch tends to increase with higher broiler prices and decrease with increasing feed costs. Seasonally, hatch is highest in the second quarter and tends to increase over time.

Broiler Production. The broiler production equation relates the number of eggs hatched to ready-to-cook weight broiler production. Broiler producers feed animals to a certain weight range. At the margin, broiler price and feed costs affect these weight differentials from the standard. Broiler production is a function of broiler hatch the previous quarter, broiler prices, feed costs, seasonal intercept shifters, and time trend.

Broiler production (I) = (26)
Q [broiler hatch (I–1),
nine-city broiler price (I–1),
feed cost (I–1),
D1 (I),
D2 (I),
D3 (I),
time (I)]

The results of the equation indicate that the ready-to-cook weight of broilers averages about 2.35 pounds. Weight varies positively with broiler price movements and negatively with feed costs, as expected. Production has also increased over time, which cannot be fully explained by the other variables.

Consumption Equations

Consumption data on a time series basis as compiled by USDA are net disappearance numbers. Consumption data tend to contain the residuals of all components within the system.

Consumption data are estimated using an identity in the same way as they are derived by the source (USDA). Components of the identity are production (farm and commercial), beginning stocks, imports, exports and shipments, military consumption, and ending stocks. Only commercial production and stocks are endogenous within the framework of the model. These two variables are the largest components of the identity. Trade components are assumed exogenous because they depend on international events and are beyond the scope of this report. Military consumption depends on the size of the military force and on the buying strategies of the military purchasing agents, which vary from time to time.

Consumption (I) = (27)
commercial production (I)
+ farm production (I)
+ beginning stocks (I)
+ imports (I)
– exports and shipments (I)
– military consumption (I)
– ending stocks (I)

Commercial production numbers are determined in the separate production sectors and are fed recursively into the consumption section. Cold storage is the remaining endogenous variable needed in computing net disappearance. Meat placed in cold storage tends to be used in further processing and is of lower value, except for cured items such as ham, bacon, and turkey products.

Cold Storage. Cold storage stocks are assumed to follow a partial adjustment mechanism, and vary from previous levels according to production quantities and profitability. The cold storage equations are specified

[3]Weighted broiler placements are derived from laying cycle information (1).

as functions of four-quarter lags in cold storage stocks, commercial production, retail price, and seasonal shifters (table 5).

Beef cold storage (I) = (28)
Q [beef cold storage (I-4),
beef production (I),
beef retail price (I-1),
D1 (I),
D2 (I),
D3 (I)]

The results of this equation suggest that 18 percent of last year's cold storage stock is maintained, and about 5 percent of production is placed within stocks. Processors will react positively to increases in the retail price.

Pork cold storage (I) = (29)
Q [pork cold storage (I-4),
pork production (I),
pork retail price (I-1)]

Table 5—Cold storage equations

Dependent variable: Beef cold storage

	SSE 141832.7		F ratio	4.21
	DF 39		Probability-F	0.0114
	MSE 3636.737		R-square	.2445

Variable	Parameter estimate	Standard error	T ratio	Probability-T
Intercept	20.169	150.568	0.1340	0.8941
Beef cold storage(I-4)	.180	.153	1.1786	.2457
Beef production(I)	.054	.025	2.2028	.0336
Beef price(I-1)	–.277	.218	–1.2711	.2112

Dependent variable: Pork cold storage

	SSE 83306.72		F ratio	10.60
	DF 38		Probability-F	.0001
	MSE 2192.282		R-square	.5274

Variable	Parameter estimate	Standard error	T ratio	Probability-T
Intercept	–12.889	82.682	–.1559	.8769
Pork cold storage (I-4)	.255	.126	2.0294	.0495
Pork production(I)	.072	.017	4.2635	.0001
Retail pork price (I-1)	–.417	.306	–1.3648	.1803
D2	34.438	17.613	1.9552	.0579

Dependent variable: Broiler cold storage

	SSE 664466372		F ratio	12.78
	DF 38		Probability-F	.0001
	MSE 27485957		R-square	.5737

Variable	Parameter estimate	Standard error	T ratio	Probability-T
Intercept	439510.7	1273614	.3451	.7319
Broiler cold storage (I-1)	.624	.116	5.3590	.0001
Broiler production(I)	.005	.004	1.0369	.3063
9-city broiler price (I-1)	–190.900	149.373	–1.2780	.2090
Time	–218.883	651.389	–.3360	.7387

Seasonal intercept shifters are statistically insignificant in this equation. Approximately 25 percent of the previous year's pork stocks are held as a base and about 7 percent of current quarter production is added to stocks each quarter. The higher percentage of pork held in cold storage reflects the larger number of cured pork products. The farm-to-retail price ratio tends to positively affect cold storage stocks.

Broiler cold storage (I) = (30)
Q [broiler cold storage (I–4),
broiler production (I),
broiler retail price (I–1),
time (I)]

Results of estimating the broiler cold storage equation indicate that about 63 percent of the previous year's stocks are maintained as a base. Due to problems obtaining a consistent time series that reflects the retail broiler price, the nine-city broiler price is used. The nine-city broiler price has a positive effect on stocks price. The time trend variable indicates that processors tend to hold fewer broilers in cold storage over time.

Retail-Weight Per Capita Consumption. The model computes consumption as a net disappearance number using the estimates of cold storage stocks. This is the same methodology used by USDA in deriving consumption data.

Per capita consumption on a retail-weight basis is then derived for each meat category for use in the price determination section. Each different meat type has a different cutout percentage used to convert from carcass to retail weight. This cutout percentage is the amount of bone, fat, and other edible and inedible byproducts removed from the carcass as it is transformed to the retail cut purchased by consumers. The beef retail conversion factor has a constant percentage cutout rate of 74 percent. Pork cutout varies according to the amount of lard production. A lard production estimate is beyond the scope of the model, however, and the dressing percentage for hogs tends to vary between 0.92 and 0.935, with 0.93 chosen as a standard. Broilers are sold on a carcass (ready-to-cook) basis, so no cutout factor is used to convert carcass to retail weight.

Price Determination Equations

The price determination equations estimate the price at which the market will clear. Underlying these equations are several assumptions about the behavior of the meat marketing process. First, meat supplies are highly inelastic within a quarter, due to the time-consuming nature of the production process. Most meat is also storable only at a high opportunity cost, which increases the inelasticity of supply. Coupled with high storage costs is the relatively short shelf life of meat products, forcing the marketing pipeline to keep moving. Second, both consumers and producers are price takers. On the production side, future supplies are adjusted according to prices producers receive. Consumers as individuals adjust their purchases according to their preferences, commodity prices, and budgets. Since meat supply is inelastic during a quarter, marketing agents adjust prices until they reach a market clearing price at the retail level. Processors then use the market clearing price, the available supply of slaughter animals, and their processing cost to determine the derived demand price they are willing to pay for the live animal.

Within the logical framework of the model, prices are first determined at the retail level and then fed back to the market prices for live animals. Retail prices for beef, pork, and broilers are assumed to be a function of competing meat consumption on a per capita retail-weight basis and of per capita disposable income. Signs of the coefficients should be positive for the income variable and negative for the quantity variables. Because of limited information included in these equations about consumer demand factors, however, the signs may not conform to expectations. These equations are estimated using year-over-year percentage difference variables.

Retail price (I) = (31)
Q [per capita beef consumption (I),
per capita pork consumption (I),
per capita broiler consumption (I),
per capita disposable income (I)]

The nine-city broiler price is used instead of the retail price because of insufficient consistent time series data (table 6).

Table 6—Retail price equations

Dependent variable: Percentage change in retail beef price

SSE	0.1945	F ratio	18.81
DF	39	Probability-F	.0001
MSE	.00499	R-square	.5914

Variable	Parameter estimate	Standard error	T ratio	Probability-T
Intercept	0.012	0.059	0.198	0.8438
Percentage change in per capita beef consumption(I)	−1.228	.223	−5.504	.0001
Percentage change in per capita pork consumption(I)	−.293	.100	−2.922	.0058
Percentage change in per capita broiler consumption(I)	.443	.209	2.115	.0408
Percentage change in per capita disposable income(I)	.631	.638	.990	.3281

Dependent variable: Percentage change in retail pork price

SSE	0.1843	F ratio	67.26
DF	39	Probability-F	.0001
MSE	.0047	R-square	.8380

Variable	Parameter estimate	Standard error	T ratio	Probability-T
Intercept	−0.067	0.058	−1.157	0.2542
Percentage change in per capita beef consumption(I)	−.287	.219	−1.306	.1993
Percentage change in per capita pork consumption(I)	−1.246	.099	−12.583	.0001
Percentage change in per capita broiler consumption(I)	.461	.206	2.243	.0307
Percentage change in per capita disposable income(I)	1.541	.627	2.458	.0185

Dependent variable: Percentage change in 9-city broiler price

SSE	0.465	F ratio	23.98
DF	38	Probability-F	.0001
MSE	.012	R-square	.7163

Variable	Parameter estimate	Standard error	T ratio	Probability-T
Intercept	−0.060	0.093	−0.6439	0.5235
Percentage change in per capita beef consumption(I)	−1.199	.353	−3.4006	.0016
Percentage change in per capita pork consumption(I)	−.899	.162	−5.5502	.0001
Percentage change in per capita broiler consumption(I)	−1.639	.334	−4.9038	.0001
Percentage change in per capita disposable income(I)	1.899	1.009	1.8815	.0676

Live Animal Price Equations

Live animal prices are generated by derived demand and are a function of retail price, available supply of slaughter animals, and the cost of processing the live animal.

Steer Prices, Omaha. Steers are the highest value slaughter animals in the meat complex. Heifer and cow slaughter prices are usually discounted from the steer price (table 7). Therefore, steer prices are generally the most widely used measure of fed cattle price. Steer prices were assumed to be a function of beef retail price and both fed and nonfed steer and heifer slaughter.

Steer price (I) = (32)
Q [beef retail price (I),
fed steer and heifer slaughter (I),
nonfed steer and heifer slaughter (I)]

Fed and nonfed steer and heifer slaughter indicates the amount of product that producers must pass through the system during the quarter. Beef prices represent the marginal revenue of the processor's output.

Table 7—Farm price equations

Dependent variable: Steer price

SSE	202.206		F ratio	404.07
DF	39		Probability-F	.0001
MSE	5.185		R-square	.9688

Variable	Parameter estimate	Standard error	T ratio	Probability-T
Intercept	30.504	7.819	3.9013	0.0004
Retail beef price(I)	.254	.009	28.4626	.0001
Fed cattle marketings(I)	−.003	.001	−3.2013	.0027
Nonfed steer and heifer slaughter(I)	−.005	.0009	−5.6655	.0001

Dependent variable: barrow and gilt price

SSE	196.724		F ratio	369.61
DF	40		Probability-F	.0001
MSE	4.918		R-square	.9487

Variable	Parameter estimate	Standard error	T ratio	Probability-T
Intercept	36.602	3.580	10.2239	.0001
Retail pork price(I)	.298	.013	22.4230	.0001
Hog slaughter(I)	−.002	.0001	−11.5451	.0001

Dependent variable: Feeder steer price

SSE	1074.61		F ratio	426.41
DF	41		Probability-F	.0001
MSE	26.210		R-square	.9123

Variable	Parameter estimate	Standard error	T ratio	Probability-T
Intercept	4.618	2.41	1.9162	.06230
Breakeven feeder steer price(I)	.828	.040	20.6496	.0001

Barrow and Gilt Prices. Barrows and gilts make up 95 percent of the hogs slaughtered. This is the market price that the farmer receives for hogs produced. Barrow and gilt prices are assumed to be a function of hog slaughter and pork price.

Barrow and gilt price (I) = (33)
Q [pork price (I),
hog slaughter (I)]

Results indicate that as hog slaughter rises, processors will lower their bids to producers for the live animals. Pork producers receive an average of about 30 percent of the retail price, on an unadjusted basis.

Feeder Steer Prices, Kansas City. Feeder steers account for the largest part of a cattle feeder's budget. At the margin, individual cattle feeders are also price takers in relation to their finished product. They must gauge their bids for feeder steers on costs and returns and supplies of feeder animals.

Feeder steer price (I) = (34)
Q [breakeven feeder steer price (I)]

Feeder steer prices are the revenue of the cow-calf operator. These prices are usually determined by the profitability of the feeding process. Feeders thus look at their costs and expected returns and bid a price at which a profit can be made. Since cow-calf producers are price takers, this net margin bid usually determines the market price. Feeder steer prices are thus projected using a residual price from a budget process. Estimated net cost for the additional gain of 550 pounds is subtracted from the revenue expected from a 1,050-pound steer to give a breakeven purchase price (see app. B). Dividing this value by 600 pounds yields a breakeven feeder steer price. This latter breakeven price is regressed on the actual feeder steer price to determine the bias in the budget. The budget holds several nonfeed cost factors constant. The bias in the budget is assumed to reflect these costs, as well as the differences in breakeven prices and actual feeder steer prices.

Model Evaluation

Performance of econometric models can be measured in many ways, depending on the desired use. Several available statistics were developed to analyze specific evaluation criterion. Each statistic focuses on a specific criterion; a general weighting scheme can be applied to these statistics to determine which formulation is best. A subjective set of weights is used to value the various statistics according to the model's designed use.

This model was designed as a short-term forecasting tool for use in conjunction with the analyst for the USDA Outlook and Situation program. The evaluation focuses on the model's ability to identify directional changes. Point accuracy is not weighted as heavily as turning point accuracy, since the purpose of the model is to aid analysts in forecasting the point in time that the market would change direction.

Under the conditions defined in the development of the model, three measures of performance—percentage turning point analysis, Theil's inequality coefficient (U_2), and the mean absolute percentage error—are chosen to represent the expected performance of the quarterly model. These tests are done on the model as a system, over the period 1973-81 and 1982-84, in four-quarter intervals. Testing of the model over 1973-81 determines the performance of the model as a system of equations. The second period, 1982-84, determines the forecasting ability of the model outside the data period used in estimation.

Each of the various statistics measure a different aspect of the model's performance. The aim of any model is to forecast future value perfectly. Data information sets may not include all the information necessary to forecast perfectly, however, or may contain errors in measurement. A large proportion of the data used in this model is survey data which contain a measurement error. Models can be chosen on the basis of several criteria once the perfect forecasting model is unattainable.

Turning point analysis measures the model's ability to forecast directional changes. In livestock and poultry outlook work, analysts are interested in predicting directional change, measured as a year-over-year change. Because this model is developed for short-term forecasting, the change was done for the actual value a year ago, due to the highly seasonal nature of the livestock industry. The model uses actual values which would have been known at the time of the forecast and were used in the decision process. Appendix C contains the formulation of the evaluation statistics.

Theil's inequality (U_2) coefficients measure the model's performance as compared with a naive forecast. A naive forecast is assumed to be no change from the previous period. Again, the statistic is formulated as a year-over-year change. Actual values for the previous period are again used.

Mean absolute percentage error is a unitless measure of the model's point accuracy. Whereas previous statistics measure the model's ability to predict changes and its relative performance compared with a naive forecast, the mean absolute percentage error allows one to compare the point accuracy of the model's components.

During 1973-81 the model performs fairly well (table 8). Turning point errors are below 25 percent for all but five equations. Only the beef cold storage equation has a mean absolute percentage error greater than 10 percent and U_2 value equal to or greater than 1. The other four equations—net cattle placements, fed cattle marketings, steer and heifer slaughter, and retail pork price—are acceptable in the other criteria. Some error in fed cattle marketed could be related to the directional misses by the net cattle placements equations. Four equations have mean absolute percentage errors greater than 10 percent; of these, three were cold storage equations. The behavior of the cold storage industry is somewhat more complex than the behavioral equation. Information necessary to predict cold storage more accurately is not avail· ble, however. Beef cold storage is the only equation to perform as well as a naive forecast.

The model is evaluated for 1982, 1983, and 1984, periods outside the data base used in the estimation (table 9 and 10). The model does not forecast well for 1982, but forecasting ability improves over the other two periods. The model's inability to project some of the changes during these periods is expected given various government programs, economic conditions, and drought.

The model also does not do well in projecting turning point errors during 1982. Agriculture was beginning to realize the impact of falling land values and was experiencing cash flow and financial difficulties. Farmers did not heed many of the historical expansion signals. Increased financial stress caused producers to sell breeding stock and young female animals to raise cash. The model does a much better job of catching the turning points by 1983. Tables 9 and 10 show the comparison between the model's performance during 1982, 1983, and 1984. Between 1982 and 1983, the model has nine equations which misses fewer turning points and five which had more errors. Eleven of the equations catch more turning points in 1984 than in 1982. The model's ability to catch turning points is a positive indication of forecasting ability.

Mean absolute percentage errors (MAPE) are larger than expected for 1982. These errors are considerably lower in 1983 than in the previous year. The MAPEs increase in 1984 over 1983, but are still below the 1982 levels. Impacts from the Payment-in-Kind pro-

Table 8—Evaluation statistics for 1970–81

Variable name	Turning point error percentage	Mean absolute percentage	Theil U_2
Cow slaughter	13.0	12.40	0.64
Net cattle placement	29.0	7.97	.69
Fed cattle marketed	26.0	5.13	.63
Fed cattle slaughter	10.0	1.15	.15
Steer and heifer slaughter	35.0	.97	.68
Cattle avg. dressed weight	19.0	1.59	.51
Sow farrowings	14.0	3.68	.38
Sow slaughter	11.0	6.74	.38
Barrow and gilt slaughter	11.0	3.84	.44
Broilers placed in hatchery supply flocks	19.0	5.35	.61
Broiler hatch	19.0	3.08	.59
Broiler production	10.0	2.94	.48
Beef cold storage	29.0	12.35	.65
Pork cold storage	23.0	11.90	.76
Broiler cold storage	16.0	10.32	.36
Percentage change in retail beef price	10.0	.06	.42
Percentage change in retail pork price	32.0	.05	.20
Percentage change in 9-city broiler price	13.0	.08	.28
Steer price	13.0	3.82	.29
Barrow and gilt price	30.0	4.26	.30
Feeder steer price	13.0	8.00	.36

gram for crops and the Payment-in-Cash program for dairy, coupled with the drought late in 1983 and 1984, were felt more in 1984 by livestock producers. These factors reduced crop production, and increased feed prices and cow slaughter. Only three of the mean absolute errors in 1983 are above 10 percent. While this number rises to six in 1984, two of the equations are from the cold storage sector (a minor factor). One equation, cow slaughter, increases as a result of the dairy program and the drought.

For the last performance statistic, the Theil U_2 test, the model appears to do worse in many cases than a no-change forecast. This statistic is not as disappointing, however, when examined in context with factors affecting the livestock sector during this period. Producers held production levels over this period while the financial crisis affecting agriculture, in the form of high real interest rates and the declining willingness of the banks to finance expansion, took place. This was done even in the face of expansion signals from input and output prices. The model does not pick up these changes because they are more qualitative than quantitative. The lack of supply response, coupled with changing income distributions among households over this period, gave less strength to demand than the per capita income data indicate. Beef retail prices remained flat with no real change in consumption levels and with 5-10 percent increases in personal disposable income.

Given the deep U.S. and world recessions, the number of farm bank failures, and changes in Government programs, the model's performance during the periods examined was acceptable. All of the exogenous factors were new to the sector; as these shocks wash out and the agricultural economy becomes more stable, model performance should improve.

Table 9—Evaluation statistics for the period 1982, 1983 and 1984

Variable name	Turning point error percentage			Mean absolute percentage			Theil U_2		
	1982	1983	1984	1982	1983	1984	1982	1983	1984
Cow slaughter	75.0	50.0	50.0	16.6	6.3	15.2	1.85	1.7	1.2
Net cattle placements	25.0	25.0	25.0	6.07	8.4	8.0	.61	1.3	.72
Fed cattle marketed	25.0	25.0	50.0	5.07	2.0	4.1	1.34	.63	2.05
Fed cattle slaughter	25.0	25.0	25.0	5.02	2.7	3.5	.99	.72	1.64
Steer heifer slaughter	50.0	25.0	0	6.14	2.36	1.5	4.08	1.3	.72
Cattle average dressed weight	0	25.0	100.0	1.15	1.7	3.59	0.56	2.5	3.3
Sow farrowings	75.0	0	75.0	13.16	8.1	11.57	1.30	.88	.40
Sow slaughter	25.0	0	75.0	12.17	12.15	6.06	7.07	.56	.48
Barrow and gilt slaughter	0	0	0	7.07	2.1	2.6	.65	.28	.51
Broilers placed in hatchery supply flocks	75.0	50.0	25.0	13.38	12.0	27.0	1.49	8.2	4.3
Broiler hatch	50.0	75.0	25.0	1.53	5.9	8.8	1.13	3.8	2.3
Broiler production	0	75.0	25.0	1.13	65.0	33.0	.83	2.68	.47
Beef cold storage	50.0	25.0	25.0	17.60	6.5	3.7	.86	.71	.39
Pork cold storage	50.0	0	0	24.39	5.8	18.74	.97	.36	.91
Broiler cold storage	25.0	50.0	100.0	27.48	31.2	54.58	.83	1.38	1.56
Percentage change in retail beef price	25.0	75.0	50.0	5.8	5.7	9.0	2.41	2.53	3.76
Percentage change in retail pork price	50.0	50.0	0	10.0	4.0	13.0	1.19	.42	1.8
Percentage change in 9-city broiler price	25.0	100.0	0	9.2	9.1	9.0	.68	.88	.73
Steer price	50.0	50.0	25.0	15.75	5.4	7.63	4.43	2.1	1.3
Barrow and gilt price	0	0	0	12.80	8.8	6.3	.76	.22	.70
Feeder steer price	50.0	50.0	25.0	31.67	9.7	10.0	5.38	1.5	2.01

Table 10—Annual equations actual and predicted for 1982

Variable	Predicted	Actual	Percentage error
	Number		
Cows on farms January 1:			
1982	50075.50	50331.00	0.5
1983	50493.0	48493.0	3.1
1984	47948.0	48603.0	1.4
Calving rate:			
1982	.9122	.8825	3.37
1983	.907	.90	.8
1984	.905	.87	4.0
Steers greater than 500 lbs:			
1982	13678.0	15501.0	11.8
1983	16053.0	16225.0	1:1
1984	15910.0	16391.0	3.0
Heifers greater than 500 lbs:			
1982	16006.7	18328.0	12.7
1983	17465.0	18830.0	7.8
1984	15910.0	16391.0	7.2
Heifers kept for cow replacement:			
1982	10800.6	11147.0	3.1
1983	10186.0	10876.0	6.8
1984	10736.0	9950.0	7.9
Calf crop:			
1982	45678.0	44420.0	2.8
1983	43688.0	43925.0	3.1
1984	43143.0	42499.0	1.5
Actual heifers entering the cow herd:			
1982	8124.2	7174.0	13.2
1983	8058.0	7949.0	3.1
1984	7720.9	6954.0	1.4
Percentage of heifers entering the cow herd:			
1982	.7751	.6440	20.4
1983	.79	.76	3.5
1984	.77	.65	17.8

Conclusions

Development of the model emphasized replication of the behavioral patterns of the economic participants. Under the condition of limited data availability and measurement error, the model's performance was acceptable. Incorporation of the best available information did not explain all factors affecting producer or consumer behavior. Model performance during 1982-84 was affected by various exogenous forces which had not existed previously. These external shocks were either nonquantifiable or the data was not rich enough to allow the statistical methods used to extract the behavioral patterns. Strict financial behavior by agricultural loan institutions restricted the cash flow of livestock producers and hence, expansion. Low grain prices caused cattle producers in mixed enterprise operations to sell breeding animals to meet shortrun cash expenses. High unemployment and underemployment caused distributional shifts in the disposable income data which are not extractable from per capita (mean) data, but are demonstrated in annual median household income data. Changing household income causes behavioral changes by consumers that are not explained by the data in the model. The model performed better in the latter periods; as the agricultural sector becomes more stable, the performance should improve.

Improvements in the model should focus on obtaining a better measurement of the financial conditions of livestock producers. The model does not currently incorporate any financial factors. The price determination sector of the model should move more towards a simultaneous system structure. The linkages between the farm and the retail price sectors need improvement, as well as income measurement. Annual household income data show that distribution of income levels shifts during macroeconomic cycles. The information in the mean values are different as the cycles progress, leading to the overestimation of retail prices during the last few years.

Overall, the model meets the needs for which it was designed. The model has provided good means to assist outlook analysts in making short-term forecasts. The deviation of the model's forecasts caused the analyst to look closely at outside forces affecting the livestock sector. These conditions, which have affected the livestock sector over the past few years, can be used by the analyst to adjust the results of the model to make the forecasts more accurate.

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Appendix A—Efficiency Gains in the Broiler Industry

The broiler production industry has developed from a heterogeneous industry to a highly integrated industry during the past 30 years. As it moved toward more vertical integration, the broiler industry became a much more efficient user of feed grains. The appendix figure shows the gains made in feed efficiency over the past 25 years.

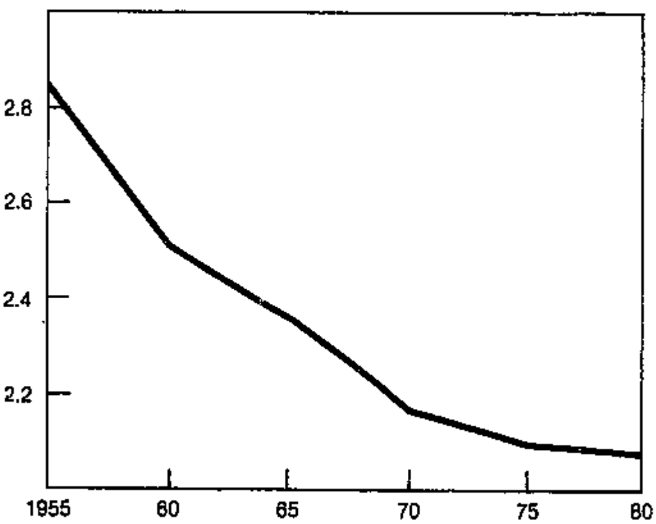
The information gained in the study of the broiler feed efficiency was incorporated within the model. Feed costs were multiplied by the feed efficiency factor, derived from the trendline depicted in the appendix figure for each year within the model framework. Broiler feed costs were defined as the weighted cost per hundredweight of corn and soybean meal multiplied by the feed efficiency factor.

Feed costs = (corn price (I)/0.56)70 +
(soybean meal price (I)/20)30 × feed efficiency factor

Appendix figure

Broiler feed efficiency trends

Pounds of feed/pounds of gain



Appendix B—Feeder Steer Price Determination Budget

Raw inputs purchased by feeders for the feeding process are feeder cattle, various feed products (corn, hay), and various services such as transportation, veterinarians, management charges, and labor. Most o these costs are fixed. At the margin cattle feeders do not move the feed grain market by their presence or absence. Other costs such as transportation, commission, or veterinarian medicine are contracted for and may be fixed for a time. The only major cost which feeders can control to any extent are bids to the cow-calf producer for feeder steers. The model assumes that the cow-calf producer is a price taker and therefore, that feeders bid against each other for the feeder cattle. The model also assumes that cattle feeders will bid a price based on their expectations of the cost of marginal weight gain of the cattle and the expected returns from the sale of the cattle.

Feeder steer prices were forecast using an expected breakeven price bid by the cattle feeders (see box). To reach a net weight gain of 500 pounds, 51 bushels of corn were assumed to be fed to cattle in the feedlot, along with 800 pounds of hay. Other costs were set at the values used in the cattle budgets published in the *Livestock and Poultry Outlook and Situation Report* (*19*). The box shows the budget used to determine the breakeven prices.

Residual feeder cattle price estimation

Feed costs
  51 bushels of corn
  400 lbs. of cottonseed meal
  800 lbs. of alfalfa hay
Interest, vet fees, death
  loss, management and other
  miscellaneous costs

\+ ______________________________

Total costs

Steer price per cwt. × 10.6
− Total costs

____

Total residual feeder steer price

Residual feeder steer price = Total residual feeder steer price/6.0

Appendix C—Evaluation Statistics

This section describes actual descriptions and formulas for the various evaluation statistics chosen for this model, including turning point analysis, Theil's U_2, mean absolute percentage error.

Turning Point Analysis

Turning point analysis is used to determine the model's ability to predict directional changes. Turning point analysis measures the percentage of times the model diverges from the actual directional change. This analysis does not attempt to measure point accuracy, and simply counts the number of misses. Directional change within the model framework is measured on a year-over-year basis.

The directional change in the present analysis is measured as a year-over-year change (first quarter this year minus first quarter in the previous year). A quarter-over-quarter change would be influenced more by seasonal direction changes than by economic directional changes because the livestock and poultry industry is highly seasonal and would be extremely biased in favor of the model. Turning point error is measured by subtracting the actual value four quarters earlier from the forecasted and actual values for the present time period. These two values are then multiplied by each other. Each time that the product is negative is counted as a turning point error. The number of misses is divided by the number of forecast periods to derive the percentage of periods which were turning point errors.

Given the circumstances under which the model is evaluated, the peformance under the turning point criterion is acceptable. Because of the interdependent nature of this model, the direction errors in one equation can affect the direction of other equations.

Mean Absolute Percentage Error. Mean absolute percentage error (MAPE) measures point accuracy, expressed as a percentage (unitless measure).[1] Mean absolute percentage error gives a better measurement of point accuracy than a mean square error statistic because an absolute error measurement is not as biased by large errors as a root mean square error. The formulation of this statistic is:

$$MAPE = \Sigma\ [(/actual_t - predicted_t/) - actual_t]/N$$

N = number of observations

Theil's U_2 Coefficient. Theil's U_2 coefficient measures the relative worth of a equation as compared with a naive model (as change). The formulation of the U_z for the model is:

$$U_2 = \left[\frac{\Sigma((actual_t - actual_{t-4}) - (predicted_t - actual_{t-4})^{-2}}{\Sigma((actual_t - actual_{t-4})^2)} \right]^{0.5}$$

Theil's U_2 is bounded by 0 and infinity, with the model better than a naive forecast if the U_2 value is less than 1. A year-over-year change was chosen over a quarter-over-quarter change for the same reason as for the turning point analysis.

[1]The retail price equations are measured in percentage changes. The absolute percentage errors thus are large. For example, if retail beef price is at $2.30 and the actual change measured is 2 percent, or 4.6 cents, and the model predicts a 4-percent change or 9.2 cents, the error is only 2 percent when measured against the actual value. If the error is measured against the percentage change, however, then the average absolute error is 100 percent. The dependent variable was converted to actual price levels and the evaluation was done on the actual price levels.

Appendix table 1—Variables and sources used in the estimation of the model

Variable	Source
Annual variables:	
Cattle:	
Cow inventory	SRS, USDA
Calf crop	SRS, USDA
Steers greater than 500 lbs.	SRS, USDA
Heifers greater the 500 lbs.	SRS, USDA
Heifers kept for cow replacement	SRS, USDA
Calves less than 500 lbs.	SRS, USDA
Calving rate	Derived
Percentage of heifers entering the cow herd	Derived
Actual heifers entering the cow herd	Derived
Annual feeder steer price	AMS, USDA
Real hay price index	AMS, USDA
Cow slaughter index	Derived
Quarterly variables:	
Cattle:	
Cow slaughter	SRS, USDA
Net cattle placements	SRS, USDA
Cattle on feed	SRS, USDA
Total cattle on feed	SRS, USDA
Fed cattle marketed	SRS, USDA
Fed steer and heifer slaughter expansion factor	Derived
Fed steer and heifer slaughter	ERS, USDA
Commercial steer and heifer slaughter	SRS, USDA
Nonfed steer and heifer slaughter	ERS, USDA
Cattle slaughter	SRS, USDA
Average dressed weight for cattle	SRS, USDA
Beef production	SRS, USDA
Hogs:	
Sow farrowings	SRS, USDA
Pig crop	SRS, USDA
Barrow and gilt slaughter	SRS, USDA
Hog slaughter	SRS, USDA
Pork production	SRS, USDA
Broilers:	
Broilers pullets placed in hatchery supply flocks	SRS, USDA
Broilers—Cont.	
Broiler hatch	SRS, USDA
Broiler production	SRS, USDA
Weighed broilers placed in hatchery supply flocks	Derived
Cold storage:	
Beef cold storage (end of quarter)	SRS, USDA
Pork cold storage (end of quarter)	SRS, USDA
Broiler cold storage (end of quarter)	SRS, USDA
Consumption:	
Beef consumption	Derived
Pork consumption	Derived
Broiler consumption	Derived
Retail price:	
Beef retail price	ERS, USDA
Pork retail price	ERS, USDA
Broiler 9-city price	AMS, USDA
Farm price:	
Steer price 0-11 cwt. Omaha	AMS, USDA
Feeder steer price 6-7 cwt. Kansas City	AMS, USDA
Barrow and gilt 7-market price	AMS, USDA
Exogenous:	
Corn price	AMS, USDA
Hay price	AMS, USDA
GNP deflator	U.S. Dept. of Commerce
Beef farm production	SRS, USDA
Pork farm production	SRS, USDA
Broiler farm production	SRS, USDA
Beef imports	U.S. Dept. of Commerce
Pork imports	U.S. Dept. of Commerce
Beef exports and shipments	U.S. Dept. of Commerce
Pork exports and shipments	U.S. Dept. of Commerce
Broiler exports and shipments	U.S. Dept. of Commerce
Beef military consumption	U.S. Dept. of Defense
Pork military consumption	U.S. Dept. of Defense
Broiler military consumption	U.S. Dept. of Defense
U.S. civilian population	U.S. Bureau of Census
Disposable personal income	U.S. Dept. of Commerce

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