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An Update and Re-Estimation of the ERS Livestock Baseline Model

Practitioner's Abstract

This report describes a re-estimation of the Economic Research Service (ERS) domestic livestock baseline model. The model consists of production, demand, and price transmission sections for the beef, pork, broiler, and turkey sectors. The updated model largely maintains the overall structure of the current model and mainly focuses on re-estimating the equations with current data. However, major changes were made to the consumer demand part of the baseline model. The current model uses an "inverse demand" model. Inverse demand models take the quantities available to consumers and then calculate the prices that will make consumers buy those quantities. The version presented in this paper uses a quantity dependent system. The equations calculate how much beef, pork, chicken, and turkey consumers will want to buy given the prices of the four meats and consumer income. This updated livestock baseline model could aid the ERS in making ten-year projections for the United States livestock sector.

Key Words: forecasting, supply and demand, structural econometric model

Introduction

The United States Department of Agriculture (USDA) makes annual ten-year projections for the food and agriculture sector that cover major agricultural commodities, agricultural trade, and aggregated indicators of the U.S. farm sector. These projections are published in an annual report with the most recent being "USDA Agricultural Projections to 2028". These projections are also included in the Economic Report of the President where they have direct impact on policy decisions. To make these ten-year projections, the USDA relies on expert opinion and a variety of baseline models. The baseline models are the responsibility of the Economic Research Service (ERS).

The annual domestic Livestock and Poultry Baseline Model (LPBM) is used to make the ten-year projections for the United States livestock sector. The LPBM is part of the larger baseline project that includes partial equilibrium models for: corn, soybeans, wheat, barley, sorghum, oats, cotton, rice, fruits and vegetables, sugar, dairy, a farm income module, and over 40 country modules. The LPBM is a stand-alone model. LPBM needs feed-cost projections from the grain and oil-seeds models, trade projections from the other baseline models, and macro-economic forecasts. The model was first implemented in the 1970s. The beef sector in the LPBM has the largest number of equations. Weimar and Stillman (1990) described the current form of the model.

In 2002, the United States General Accounting Office (GAO) issued a report (Kingsbury, Bausell, and Ashery, 2002) on issues with the LPBM and ways that it could be improved. The GAO criticized the LPBM for using old coefficients. The concern at that time was that the domestic livestock industries had undergone substantial structural change and that the coefficients were no longer valid. Structural change has continued since the GAO report was released. The use of old coefficient estimates has caused the LPBM to become increasingly reliant on the use of "add factors." Add factors are intercept shifts that are manually entered into the LPBM. Like all economic models, the LPBM is a simplification of reality. Add factors allow analysts to incorporate additional information into the LPBM. For example, a major disease outbreak or drought can restrict livestock supply. Analysts can deal with these non-modeled factors using add factors. Add factors also allow the analysts to incorporate expert opinion about future conditions in the LPBM's forecasts.

The downside to incorporating add factors is that analysts may also use add factors to cover up deficiencies of the LPBM. Add factors reflect subjective opinions of commodity experts and hurt the credibility of the model.

The purpose of the research described in this report was to update and re-estimate the LPBM. The LPBM is a structural dynamic model. When economists use the term “structural” they are referring to models with explicit supply and demand (and possibly other) equations. The term “dynamic” in this case means that current market conditions are driven in part by what happened last year.

The equations in the LPBM are in three main sections: demand, production, and price transmission. The production section is further divided into cattle-beef, hog-pork, chicken, and turkey subsections. The production and price transmission sections’ equations are based on the current baseline model. The production equations of the LPBM are where most of the dynamics enter the LPBM. Large parts of the supplies of beef, pork, chicken, and turkey are driven by last year’s conditions. The goal for the production and price transmission sections was to maintain the overall structure of the model and re-estimate the equations with recent data. Variables were added or removed from the production and price transmission equations when appropriate. Substantial changes were made to the specification of the demand section. These are discussed below.

The current LPBM is based on the work of Weimar and Stillman (1990), which itself is based on the earlier quarterly model of Stillman (1985). The LPBM has the same basic structure as Weimar and Stillman. Coefficients from that paper differ from the coefficients in the GAO report. The LPBM coefficient estimates were updated a number of times after the GAO report. The current coefficients are in the Excel spreadsheet used by the ERS to provide the annual baseline projections. The ERS model spreadsheet contains all equations and data for the model that ERS uses when solving the baseline model. There have been a few changes in the spreadsheet model since the GAO report, but there is no formal documentation of these changes.

This report is organized as follows. The three sections of the model—demand, supply, and price transmission-are each discussed separately. For each section of the model we present the updated equations and then discuss results and comparisons with the current model. When the ERS model spreadsheet has changed since the GAO report, both sources are discussed.

Demand Section

The original model estimated retail demand using Huang’s (1989) inverse demand system as documented in Weimar and Stillman (1990). An inverse demand system starts with the quantities available to consumers, then solves for the set of prices that would get consumers to buy that given set of quantities. Huang’ original demand system had five equations relating the percentage change in retail consumer price index (CPI) for beef and veal, pork, frying chickens, turkey, and nonfood to changes in the quantities of these items and total consumer expenditures. Huang’s demand system was modified so that it explained changes in the CPI for the four meats given the four meat quantities, the CPI for non-food and consumer expenditures. Weimar and Stillman (1990) stated that further work needed to be done to get a better fit of the demand model. They found only the own-price flexibilities were significant. The GAO report shows that work continued on the demand model as the cited equations contain different exogenous variables than the Weimar and Stillman (1990) paper. The GAO report cites coefficient estimates though some estimates are cited as an equation containing numbers of unknown origins while other coefficients are plainly cited. The ERS model spreadsheet uses the same model as the GAO report and contains coefficient estimates similar to the GAO report coefficients that are known so it is assumed that the demand model in the ERS spreadsheet has not been updated since the GAO report.

We initially sought to replicate the inverse demand model. An exact match of the current model was not achieved. The original data sources were not fully documented and so we likely did not use the same exact data. The estimated price flexibilities were mostly all statistically insignificant. Due to the weakness of the results from the inverse demand model, a traditional quantity dependent demand system is used instead. Also, researchers at the ERS expressed preference for the quantity dependent approach.

We initially estimated a quantity dependent Rotterdam demand model for beef, pork, chicken and turkey while imposing the demand restrictions of adding up, homogeneity, and symmetry using a SUR estimation method. The estimated model returned statistically insignificant coefficients and positive own price elasticities for turkey. The demand restrictions also were rejected. Due to the weak performance of the estimated model we decided to use a Bayesian SUR estimation procedure.

Bayesian Estimation

With Bayesian estimation, coefficients are random variables instead of unknown constants. The Bayesian estimation combines prior information with the information in the data. The prior distribution represent a belief about what the elasticities should be. Multiplying this prior distribution by the likelihood function from the data leads to a posterior distribution of the coefficient. This Bayesian approach allows incorporating the demand restrictions into the elasticity estimates through the priors along with allowing the real world data to influence the estimation. The specific approach we use is Bayesian SUR estimation. Various papers have incorporated Bayesian estimation into the estimation methods of demand systems (Bilgic and Yen, 2014; Chalfant et al., 1991; Hasegawa et al., 1999; Kasteridis et al., 2011; Kasteridis and Yen, 2012; Tiffin and Tiffin, 1999).

The estimation in this report uses a log-log model. In a log-log model, the estimated coefficients are the elasticities. This fact simplifies the interpretation of the priors on the coefficients. Another reason to estimate elasticities using a log-log demand model is that it matches the functional form that will be used in the livestock model. Demand elasticities are estimated for beef, pork, broilers, and turkey. Assuming weak separability, we estimate the demand equations for just the meat group. The dependent variables are the change in log quantity consumed per capita of the four different meats. The independent variables are the change in log prices of the four meats and the change in log expenditure for meats. The demand system consists of four equations and is specified

$$(1) \qquad dlogQ_j = \alpha_i + \sum_{i=1}^{4} \beta_{i,j}\, dlogP_i + \eta_j dlogExp + \varepsilon_j$$

where $i = \{Beef, Pork, Chicken, Turkey\}$, $j = \{Beef, Pork, Chicken, Turkey\}$, $\beta_{i,j}$ when $i = j$ is the conditional own-price elasticity, }, $\beta_{i,j}$ when $i \neq j$ is the conditional cross-price elasticity, and η_j is the expenditure elasticity.

The estimates from (1) are conditional elasticities. The model assumes a multi-step budgeting process where budget allocations for different groups are made independently. We employ the measures from Edgerton (1997) that incorporate the higher stages of the multi-stage budgeting process to estimate unconditional or total elasticities. What is needed from these higher stages of the multi-stage budgeting process are own price and expenditure elasticities for meats. While it is possible to estimate these using either a complete or incomplete demand system, for our purposes there is no clear gain in doing so. An attempt was made to estimate a complete demand system, but due to data restrictions and the insignificance of the estimated coefficients the value of the system was questionable. For simplicity, these elasticities are estimated with the following equation

$$(2) \qquad dlogQ_{Meat} = \alpha_0 + \delta_1 dlogP_{Meat} + \lambda_1 dlogDisIncome + \nu$$

where the dependent variable is the quantity of meat consumed per capita in pounds, independent variables are a weighted price of meat and disposable Income, δ_1 is the own-price elasticity of meat and λ_1 is the Income elasticity of meat.

The correction measures from Edgerton (1997) to convert the estimated conditional elasticities to total elasticities use estimates from equations (1) and (2). The correction measures are

$$(3) \qquad Total\ Income\ Elasticity: \qquad E_i = \hat{\lambda}_1 \cdot \hat{\eta}_i$$

$$(4) \qquad Total\ Price\ Elasticity: \qquad e_{ij} = \hat{\beta}_{ij} + \hat{\eta}_i \cdot w_i \cdot [1 + \hat{\delta}_1]$$

where E_i is the total income elasticity, e_{ij} is the total price elasticity, $\hat{\lambda}_1$ is the estimated income elasticity of the meat group, $\hat{\eta}_i$ is the estimated expenditure elasticity of meat *i*, $\hat{\delta}_1$ is the estimated own-price elasticity of the meat group, $\hat{\beta}_{ij}$ is the estimated price elasticity of meat *i* and *j*, and w_i is the budget share of meat *i.* These estimated total expenditure elasticities will be used to get the baseline projections.

Determining Priors

For the Bayesian estimation, a normal prior was used. To get the mean of the priors we first begin with prior means for equation (2). These priors can be found in table 1 and come from work by Muhammad et al (2011). The intercept coefficient in equation (2) has a prior mean of zero.

Remember that we are estimating conditional elasticities in equation (1) but we are really concerned with the resulting total elasticities once equations (3) and (4) are applied. Thus when we are determining the priors for the conditional elasticities, we begin by choosing prior total price and income elasticities for each meat and then transform them to unconditional elasticities by rearranging equations (3) and (4). Prior total elasticities are initially based on elasticity measures provided by the Food and Agricultural Policy Research Institute (FAPRI). The resulting unconditional elasticities obtained by the transformation of the prior total elasticities are then used as the prior unconditional elasticities means.

Prior means for total elasticities and conditional elasticities are in tables 2 and 3. The prior means for conditional elasticities were used to estimate equation (1) using the RsurGibbs package in R. To determine the prior variances, the equations are estimated using non-Bayesian SUR to obtain standard errors on the parameters that are then squared and set as the prior variances for each parameter. This method gives the priors and data equal weight in the Bayesian estimation procedure.

Results

The estimated total demand elasticities are in table 5. The own price elasticities for each meat are negative as theory would suggest. Pork is the most responsive to a price change with an own price elasticity of -0.475. This estimate is also similar to the prior imposed. The estimated own price elasticity of beef is -0.348 and is lower than the prior of -0.52. The broiler and turkey own price elasticities are also lower than the priors. It should also be noted that all total own price elasticities are lower than the estimated conditional own price elasticities. Without the correction method, the conditional elasticities would have over stated the price responsiveness for each meat.

The estimated total expenditure elasticities are all positive and show each meat to be a normal good. The estimated total expenditure elasticities are also lower than the estimated conditional expenditure elasticity.

The Cattle and Beef Sector

Background

The cattle and beef sector is the most complex and longest production process in the model. Gestation in cattle is around 285 days and most calves are born in the spring. Calves are born at about 65 pounds and raised on the cow until they reach a weaning weight of around 550 pounds. From birth till weaning can take anywhere from 90 to 205 days. Upon weaning there are multiple routes an animal can take before arriving at a feedlot. The route that an animal takes from weaning to slaughter depends on various economic and environmental factors.

Pre-conditioning is a short stage in which animals are transitioned to eating dry feeds. Pre-conditioning is beneficial for the animal's health and lasts about 35 days until the animal is sent to a feedlot to be fed out. Once at the feedlot it takes around 230 days for the animal to reach slaughter weight. Pre-conditioned cattle might also be sent to graze on summer or winter grass before being sent to the feedlot. Backgrounding is a stage were weaned animals are fed on dry forage, silage, and grain until about 800 pounds and then sent to the feedlot. Backgrounding can last for about 100 days. Once at the feedlot, it takes around another 160 days for the animal to reach slaughter weight. A final route a weaned animal can take to the feedlot is the stocker stage. Weaned animals are fed dry forage over the winter and then grazed on summer grasses before being sent to the feedlot. This stage can last almost a year. These animals will then spend around 100 days in the feedlot where they will reach slaughter weight.

Data

The data for the cattle and beef sector consists of two different types. The first type is inventory data. Inventory data represents a snapshot in time on January 1st. The data shows how many animals for each variable were on hand January 1st of each year. The variables included are beef cow inventory, steers larger than 500 pounds, other heifers larger than 500 pounds, heifers larger than 500 pounds kept for beef cow replacement, bulls larger than 500 pounds and calves smaller than 500 pounds. All cattle inventory data comes from the January 1 NASS Cattle Report.

The second type of data is a flow. Instead of being a snapshot in time, flow data gives total production for a year. The variables included in this type of data are calf crop, steer slaughter, heifer slaughter, bull slaughter, cow slaughter, and cattle slaughter weights.

Equations

Beef cow inventory reflects the number of beef cows on January 1 and provides a measure of the present and future production capacity of the cattle and beef sector. The beef cattle inventory of year *t* is thus a function of what happened in the previous year. The equation is a function of the beef cattle inventory in the previous year, the number of replacement heifers kept in the previous year, and the number of animals slaughtered in the previous year. The equation for beef cow inventory is

$$(5) \qquad Beef\ Cow\ Inventory_t = \ ca10\ + ca11 * Beef\ Cow\ Inventory_{t-1}$$
$$+ ca12 * Beef\ Replacement\ Hiefers_{t-1} + ca13 * Beef\ Cattle\ Slaughter_{t-1} + \ \mu_t.$$

Calf crop is the total number of calves born in a given year and includes both beef and dairy calves. Calf crop in year *t* is a function of the total cow inventory on January 1st of year *t.* The equation is

$$(6) \qquad Calf\ Crop_t = ca21 * (Beef\ Cow\ Inventory_t + Dairy\ Cow\ Inventory_t)\ +\ \mu_t.$$

Steers larger than 500 pounds is a January 1st inventory. It is a function of an adjusted previous year calf crop. Calf crop is adjusted for calf slaughter, cattle imports and exports. The equation is

$$(7) \qquad Steers_t = ca30 + ca31 * (\ Calf\ Crop_{t-1} - Calf\ Slaughter_{t-1}$$
$$+ Cattle\ Imports_{t-1} - Cattle\ Exports_{t-1}) +\ \mu_t.$$

Other heifers larger than 500 pounds is a January 1st inventory. It is a function of an adjusted previous year calf crop and cow calf producer returns. The equation is

$$(8) \qquad Other\ Heifers_t = ca50 + ca51 * (\ Calf\ Crop_{t-1} - Calf\ Slaughter_{t-1}$$
$$+ Cattle\ Imports_{t-1} - Cattle\ Exports_{t-1}\ ) + ca52 * Cow\ Calf\ Returns_{t-1} +\ \mu_t.$$

Heifers larger than 500 pounds kept for beef cow replacements is a January 1st inventory. Replacement heifers are kept to replenish the cow herd and are a function of the previous year beef cow inventory and lagged cow calf producer returns. The equation is

$$(9) \qquad Beef\ Replacement\ Heifers_t = ca60 + ca61 * Beef\ Cow\ Inventory_{t-1}$$
$$+ca62 * Cow\ Calf\ Returns_{t-1} + ca63 * Cow\ Calf\ Returns_{t-2} + \mu_t.$$

Bulls larger than 500 pounds is a January 1st inventory. Bulls are usually kept for breeding purposes and is a function of total cow inventory. The equation is

$$(10) \qquad Bulls_t = ca70 + ca71 * (Beef\ Cow\ Inventory_{t-1} + Dairy\ Cow\ Inventory_{t-1}) + \mu_{t.}$$

Calves smaller than 500 pounds is a January 1st inventory. It is a function of adjusted calf crop and the equation is

$$(11) \qquad Calves_t = ca80 + ca81 * (\ Calf\ Crop_{t-1} - Calf\ Slaughter_{t-1}$$
$$+ Cattle\ Imports_{t-1} - Cattle\ Exports_{t-1}) + \mu_t.$$

Steer slaughter is the total number of head of federally inspected steers slaughtered in a given year. It is a function of steers larger than 500 pounds on January 1 of the given year times the ratio of federally inspected slaughter (FI Ratio) and the cost of feeding.

$$(12) \qquad Steer\ Slaughter_t = ca90 + ca91 * (Steers_t * FI\ Ratio_t)$$
$$+ca * 92 * (Calves_t * FI\ Ratio_t) + \mu_t$$

Heifer slaughter is the total head of federally inspected heifers slaughtered in a given year. It is a function of all heifers greater than 500 pounds, dairy cattle inventory, and cow calf returns. The equation is

$$(13)\ Heifer\ Slaughter_t = ca100 + ca101 * (Other\ Heifers_t + Beef\ Replacement\ Heifers_t) * FI\ Ratio_t + ca102 * Dairy\ Cattle\ Inventory + ca104 * Cow\ Calf\ Return_t + ca105 * Cow\ Calf\ Returns_{t-1} + \mu_t.$$

Cow slaughter is the total head of federally inspected cows slaughtered in a given year. It is a function of total head of cattle on January 1st of the given year and cow calf producer returns. Producers will keep more head of cows when they are more profitable. The equation is

$$(14)\quad Cow\ Slaughter_t = ca130 + ca131 * (Beef\ Cow\ Inventory_t + Dairy\ Cow\ Inventory_t) * FI\ Ratio_t + ca132 * Cow\ Calf\ Returns_{t-1} + \mu_t.$$

Bull slaughter is the total head of federally inspected bulls slaughtered in a given year. It is a function of total head of cattle on January 1st of the given year. The equation is

$$(15)\quad Bull\ Slaughter_t = ca140 + ca141 * (Beef\ Cow\ Inventory_t + Dairy\ Cow\ Inventory_t) + \mu_t.$$

Cattle carcass weight is a function of a time trend due to genetic and technology advancement and the real price of corn which is a major component in feeding. The equation is

$$(16)\quad Cattle\ Carcass\ Weight_t = ca150 + ca151 * time\ trend_t + ca152 * Corn\ Price_t + \mu_t.$$

Results

Estimated coefficients for the cattle and beef sector are in tables 7-18. The current equations for the beef cow sector are in the GAO report. We next discuss some of the major differences between the current and updated models and the resulting coefficient estimates.

A change in the updated model is the exclusion of cow-calf returns from the beef cow inventory and calf crop equations. Cow-calf returns represent the net returns each year per cow. These returns are estimated and provided by the ERS. In the updated model, cow-calf returns affect the beef cow inventory through their inclusion in the heifers kept for beef cow replacements equation and cow slaughter equation. These are the two instances where returns play a role on decisions to retain heifers or sell older cattle.

The heifers kept for beef replacement equation contains both one lag and two lags of cow-calf returns. This is due to the data for replacement heifers contains animals that were kept for replacement heifers up to two years previous. The estimated coefficient for one lag cow-calf returns is 3.20. For every one dollar increase in cow-calf returns, the number of heifers kept for replacement will increase by 3,200 head. The estimated coefficient for two lags of cow-calf returns is 1.31 and thus for every one dollar increase in cow-calf returns two years previous the number of replacement heifers will increase by 1,310 head. These positive estimates are intuitive as higher returns mean producers will keep more replacement heifers to capitalize on the higher profit potential.

The cow slaughter equation contains one lag of cow-calf returns. The estimated coefficient in the cow slaughter equation for net returns is -3.94. For every one dollar increase in cow-calf returns, the number of cows slaughtered will decrease by 3,940 head. Marginally producing cows are more likely to be retained when returns are higher instead of being sent to slaughter.

The current model estimated an equation for heifers larger than 500 pounds. In the updated model, this is an identity that sums other heifers larger than 500 pounds plus heifers larger than 500 pounds kept for replacement. In the equation for other heifers larger than 500 pounds, cow-calf returns have an estimated coefficient of -4.81 in the updated model compared to an estimate of -7.53 in the current model. In the updated model a one dollar increase in cow-calf returns will decrease the number of other heifers by 4,810 head. This negative value is expected when returns are low, producers will retain less heifers and send the others to slaughter.

The current calf crop equation included cow-calf returns. This was removed as cow-calf returns affect calf crop by the decision to retain heifers or sell older cattle for slaughter and that effect on beef cow inventory. Calf crop in the updated equation is a function of beef and dairy cow inventory. The GAO report cites a coefficient estimate of 0.91 for this variable and the updated model estimated coefficient is slightly lower at 0.89.

The current model had steer slaughter as a function of calf crop adjusted for calf slaughter, exports, and imports. The updated model makes steer slaughter a function of steers larger than 500 pounds and calves smaller than 500 pounds. These two variables represent the available animals that can be slaughtered in the coming year. Steers larger than 500 pounds has an estimated coefficient of 0.87 and calves smaller than 500 pounds has an estimated coefficient of 0.10.

Cattle carcass weights in the updated model are estimated using a linear time trend and real corn prices. The estimated coefficient for the time trend is 5.71 and real corn prices is -10.94. When faced with higher corn prices, producers will finish cattle at a lighter weight. A concern of some in the industry is that slaughter weights are becoming too large (Maples, Lusk, and Peel 2018; Bir et al. 2018). The trend toward larger slaughter weights may end someday, but it has not happened yet. Since 2000, the slaughter weight has increased by about 75 pounds.

The Hog and Pork Sector

Background

In comparison with beef, pork production has a much shorter time frame. It takes around 6 months to raise a hog from birth to slaughter. Gestation in sows follows the old rule of lasting 3 months, 3 weeks, and 3 days. With this short gestation period, sows will have 2-3 litters in a year. When a sow is ready to give birth (farrow), they are moved to a farrowing barn where they will give birth to piglets. In 2017, the average number of pigs per litter was 10.49 compared to 8.81 in 2000. Sows will nurse the piglets until weaning at 21 days of age. At weaning, piglets are moved to a nursey where they will grow to 50 to 60 pounds. After the nursery, the pigs are then moved to a finishing barn where they will spend 16 to 17 weeks and reach market weight.

Equations

Sows farrowing is the total number of sows in a July-June year to give birth to piglets. A July-June year is used to reflect the time lag in the production of pork. The number of hogs farrowing is an indicator of the hog and pork sector's production potential. Sows farrowing is a function of lagged hog net returns. The equation is

$$(17) \qquad \Delta Sows\ Farrowing_t = hog10 + hog11 * Hog\ Net\ Returns_{t-1}$$
$$+hog12 * Hog\ Net\ Returns_{t-2} + \mu_t.$$

Pigs per litter is the number of piglets born in each litter. The number of pigs per litter has been steadily increasing from 7.89 piglets in 1990 to 10.49 piglets in 2017. Therefore, pigs per litter will be a function of a time trend and the equation is

$$(18) \qquad Pigs\ per\ Litter_t = hog50 + hog51 * time\ trend_t + \mu_t.$$

Pig crop is the total number of piglets born in a given year. Pig crop is an identity equal to the number of sows farrowing times pigs per litter. The equation is

$$(19) \qquad Pig\ Crop_t = Sows\ Farrowing_t * Pigs\ Per\ Litter_t.$$

Federally inspected barrow and gilt slaughter is the total number of barrows and gilts slaughtered in t given year. Barrow and gilt slaughter account for the majority of pork production. In 2017, barrows and gilts were 97 percent of the total hogs slaughtered. Barrow and Gilt slaughter is a function of the pig crop and the ratio of federally inspected slaughter (FI Ratio). The equation is:

$$(20) \qquad Barrow\ and\ Gilt\ Slaughter_t = hog20 * hog21 * Pig\ Crop_t * FI\ Ratio_t + \mu_t.$$

Federally inspected sow slaughter is the total number of sows slaughtered in a given year. It is a function of sows farrowing and the FI ratio. The equation is

$$(21) \qquad Sow\ Slaughter_t = hog30 + hog31 * Sows\ Farrowing_t * FI\ Ratio_t + \mu_t.$$

Boar Slaughter is the total number of boars slaughtered in a given year. It is a function of sows farrowing. The equation is

$$(22) \qquad Boar\ Slaughter_t = hog40 + hog41 * Sows\ Farrowing_t + \mu_t.$$

Hog slaughter weight is the average slaughter weight of all types of hogs. The equation is

$$Hog\ Slaughter\ Weight_t = hog60 + hog61 * time\ trend_t.$$

Results

The estimated pork sector equations are in tables 19-24. Equations of the current model can be found in the GAO report. Net hog returns are included in the sows farrowing equation. Net hog returns are calculated and provided by the ERS. They represent the net returns on one hog farrow to finish operation or farm. The updated equation maintains the same form as the current model with the exception of the removal of the 1975 dummy variable. Returns have a smaller effect on the change in pigs farrowing in the updated equation. The GAO report cites an estimated coefficient of 85.17 for returns lagged one period and 39.34 for returns lagged two periods. The ERS model spreadsheet uses a coefficient of 85.17 for returns lagged one period and 19.67 for returns lagged two periods. The updated coefficient estimates are 19.82 for returns lagged one period and 19.01 for returns lagged two periods. In the updated change in sows farrowing equation, a one dollar increase in net hog returns the previous year would increase the change in sows farrowing by 19,820 head and a one dollar increase in net hog returns two years previous would increase the change in net hog returns by 19,010 head.

The updated model adds a pigs per litter equation that was not in the current model. In the current model, pig crop was calculated as sows farrowing times pigs per litter. Pigs per litter was held at a constant rate. Due to the continuing increase in pigs per litter over time, the updated model estimates pigs per litter using a linear time trend. The estimated time trend coefficient is 0.09 and indicated that pigs per litter will increase by 0.09 each year.

The Broiler Sector

Background

Broiler production is the quickest production process in the model. It begins with parent breeders. These are the hens that lay fertilized eggs that will hatch into broiler chicks. These laying hens begin producing eggs around 24 weeks of age and can lay efficiently for 40 weeks per cycle and lay around 150 – 180 eggs per year. Eggs are collected and placed into incubators for hatching. It takes 21 days for the egg to hatch. Upon hatching the chicks are processed and moved to a grow-out farm within 12 hours. Once at the grow-out farm, it takes about 5 weeks for the broiler to reach market weight.

Equations

Broiler hatchery supply flock is the total number of broiler type laying hens in a given year. This number represents production potential. Hatchery supply flock is a function of the previous year hatchery supply flock. The equation is

$$(23) \qquad Hatchery\ Supply_t = br11 * Hatchery\ Supply_{t-1} + \mu_t.$$

Broiler chicks hatched is the total number of broiler chicks hatched in a given year. It is a function of the hatchery supply flock multiplied by the number of eggs per layer. The eggs per layer is divided by 100 because the data is reported as eggs per 100 layers. Broiler chicks hatched is also a function of broiler net returns and a time trend. The equation is

$$(24) \qquad Chicks\ Hatched_t = br20 + br21 * Hatchery\ Supply_t * \left(\frac{Eggs\ per\ Layer_t}{100}\right)$$

$$+br22 * Broiler\ Net\ Returns + br23 * Time\ Trend_t + \mu_t.$$

Broiler slaughter is the total number of broilers slaughtered in a given year. Broiler slaughter is a function of chicks hatched and the equation is

$$(25) \qquad Broiler\ Slaughter_t = br31 + br32 * Chicks\ Hatched_t + \mu_t.$$

Broilers dressed weight is a function of a time trend and the equation is

$$(26) \qquad Broiler\ Weight_t = br40 + br41 * Time\ Trend_t + \mu_{t.}$$

Results

The estimated broiler sector equations are in tables 25-28. Current model equations for the broiler sector can be found in the GAO report. The updated broiler sector equations remain similar to the current equations except for a few places. Net returns for broilers are calculated and provided by the ERS. Broiler returns represent the net returns of one pound of broiler production. Returns were statistically insignificant in the broiler hatchery supply flock equation and are excluded in the updated equation. Returns were statistically insignificant in the broiler chicks hatched equation but are included. The justification for this inclusion is hatching is the point of broiler production in which returns are considered in the decision making process. Higher returns should cause producers to hatch more chicks.

In the updated broiler chicks hatched equation, the estimated coefficient for returns is 7,275.71. A one dollar increase in the net returns of broilers will increase the number of broiler chicks hatched by 7,275,710 chicks. This effect of net returns on chicks hatched is lower than in the current model. The GAO report cites a coefficient estimate of 76,853.16 and the ERS model spreadsheet uses a coefficient estimate of 16,532.47. This provides some evidence that broiler supply has become more inelastic as the supply is less responsive to a change in returns.

The updated broiler slaughter equation drops a time trend that the current model included. Both the GAO report and ERS model spreadsheet use a coefficient of 0.756 for broiler chicks hatched in the broiler slaughter equation. The updated model estimates a coefficient of 0.94.

The updated equation for average dressed weight of broilers is changed from the current model. The GAO report cites the use of a quadratic time trend to estimate the average dressed weight of broilers. The ERS model spreadsheet uses a simple one percent year to year increase in the average dressed weight. The updated equation estimates a linear time trend with a coefficient estimate of 0.06.

Turkey Sector

Background

Turkey production is very similar to broiler production but takes a few extra weeks. The production process starts with parent breeders who lay fertilized eggs. Eggs are collected and placed into incubators where they will hatch after 28 days. After hatching, poults are processed and delivered to a grow-out farm within 12 hours. On average it takes a hen 12-14 weeks to reach market weight and toms 16-19 weeks to reach market weight.

Equations

Eggs in Incubators is the total number of eggs in incubators in a given year. This represents the production potential of the turkey sector. Eggs in incubators is a function of the past year turkey net returns and a time trend. The equation is

$$(27) \qquad Eggs_t = turk10 + turk11 * Turkey\ Net\ Returns_{t-1} + Turk12 * Time\ Trend_t + \mu_t.$$

Net poults placed is the total number of poults placed in growing houses in a given year. It is a function of eggs in incubators and the equation is

$$(28) \qquad Poults\ Placed_t = turk20 + turk21 * Eggs_t + \mu_t.$$

Turkey slaughter is the total number of turkeys slaughtered in a given year. It is a function of net poults placed and the equation is

$$(29) \qquad Turkey\ Slaughter_t = turk30 + turk31 * Poults\ Placed_t + \mu_t.$$

Turkey dressed weight is a function of a time trend and the equation is

$$(30) \qquad Turkey\ Weight_t = turk40 + turk41 * Time\ Trend_t + \mu_t.$$

Results

Estimated turkey sector equations are in tables 29-32. The turkey sector portion of the model is expanded from the current model. The GAO report and ERS model spreadsheet use a single equation for the turkey sector such that turkey production is a function of turkey net returns. The GAO report states that originally there were equations for supply flock and eggs hatched, but much of the data used was discontinued. With the current availability of NASS turkey hatchery data, the turkey sector model was extended to incorporate four equations.

Returns of turkey production is included into the model in the eggs in incubators equation. The decision to hatch turkeys depends on the returns that producers can receive. In the eggs in incubators equation, the estimated coefficient for turkey returns is 1,664.99. A one dollar increase in the returns for turkey would increase the number of eggs in incubators by 1,664,990 eggs. This is consistent with the expectation that higher returns will lead to the decision to hatch more eggs.

The number of poults placed in growing houses is then dependent on the number of eggs being hatched. The estimated coefficient for eggs in incubators in the poults placed equation is 0.61. For every 1,000 eggs incubated, 610 of them will hatch poults that can be placed in a growing house. Turkey slaughter is then dependent on the number of poults placed. For every 1,000 poults placed, 860 of them will make it to slaughter according to the model with an estimated coefficient of 0.86.

Dressed weight of turkey is estimated with a linear time trend. Total turkey production is determined by the number of turkeys slaughtered times the dressed weight.

Price Transmission

The demand section of the model sets the retail price for beef, pork, chicken and turkey. This retail price is then used to determine wholesale and farm level prices through a set of price transmission equations. Price transmission equations are all change equations. The decision to estimate change equations was to maintain consistency with the current form of the model. Prices are deflated by the U.S. CPI to calculate real prices. Units of the prices can be found in the results tables 33-41.

The boxed beef price is a wholesale price of beef that represents the primal cuts value. The boxed beef price is a function of the retail beef price and the equation is

$$\Delta Boxed\ Beef_t = Pr10 + Pr11 * \Delta Retail\ Price\ Beef_t + \mu_t. \tag{33}$$

The cow carcass price is a wholesale price of beef that represents the value of beef. The cow carcass price is a function of the retail price of beef and the equation is

$$\Delta Cow\ Carcass\ Price_t = Pr20 + Pr21 * \Delta Retail\ Price\ Beef_t + \mu_t. \tag{34}$$

The steer price is a farm price that represents the annual average five area average price for all grades. The steer price is a function of the boxed beef price and the equation is

$$\Delta Steer\ Price_t = Pr30 + Pr31 * \Delta Boxed\ Beef\ Price + \mu_t. \tag{35}$$

The heifer price is a farm price that represents the annual average five area average price for all grades. The heifer price is a function of the boxed beef price and the equation is

$$\Delta Heifer\ Price_t = Pr40 + Pr41 * \Delta Boxed\ Beef\ Price_t + \mu_t. \tag{36}$$

The cow price is the annual average price for slaughter cow price-boning utility-Sioux Falls, SD. The cow price is a function of the cow carcass price and the equation is

$$(37) \qquad \Delta Cow\ Price_t = Pr50 + Pr51 * \Delta Cow\ Carcass\ Price_t + \mu_t.$$

The feeder steer price is a function of the steer price and feedlot costs. The equation is

$$(38) \qquad \Delta Feeder\ Steer\ Price_t = Pr60 + \mathrm{Pr}61 * \Delta Steer\ Price + \mathrm{Pr}62 * \Delta Feedlot\ Costs + \mu_t.$$

The barrow and gilt price is the annual average of the national base 51-52% lean price. The barrow and gilt price is a function of the retail pork price and the equation is

$$(39) \qquad \Delta Barrow\ and\ Gilt\ Price_t = Pr70 + Pr71 * \Delta Retial\ Price\ Pork_t + \mu_t.$$

The broiler price is the annual average of the national composite price. The broiler price is a function of the retail poultry price and the equation is

$$(40) \qquad \Delta Broiler\ Price_t = Pr80 + Br81 * \Delta Retail\ Poultry\ Price_t + \mu_t.$$

The turkey price is the annual average 8-16 lb hen price. The turkey price is a function of retail turkey price and is

$$(41) \qquad \Delta Turkey\ Price_t = Pr90 + Br91 * \Delta Retail\ Turkey\ Price_t + \mu_t.$$

Results

Results of the price determination equations can be found in tables 33-41. The resulting equations show how a change in retail price of meat would flow down to the other prices. As an example consider how a change in the retail price of beef would change the steer price. A one dollar increase in the retail price of beef would increase the boxed beef price by $0.41. This $0.41 increase in the boxed beef price would then increase the steer price by $0.27. An increase in the retail price of beef would have about the same effect on heifer price as it does for steers. A one dollar increase in the retail price of beef would increase the cow carcass price by $0.50 and thus increase the cow price by $0.19.

Due to the simpler nature of the pork, broiler, and turkey sectors, there is only one price determination equation for each. A change in retail price would have the largest effect on broilers. A one dollar increase in the retail price would have a $0.58 change in the broiler price. The dressing percentages for each type of meat are approximately cattle 62%, hogs 70%, broilers 71%, turkeys 79%. So the higher price responsiveness of the broiler price to the retail price may be due to the structure of the industry rather than any difference in dressing percentage.

The current model incorporated some production variables into the price equations. These variables included the percentage change of steer and heifer production in the boxed beef price equation and percentage change of cow production in the cow carcass price equation. When these variables were estimated in the updated equations, they were insignificant and were excluded from the model since there was no strong theoretical reason for their inclusion.

Conclusions

This report presented a new approach to the annual domestic livestock baseline model. The model consists of three sections: production, demand, and price transmission. The production section consists of equations for the beef, pork, broilers, and turkey sectors. Retail meat demand is estimated using a Bayesian estimation procedure that was previously not used. Wholesale and farm level prices are determined through a set of price transmission equations. This version of model could aid USDA in making annual ten-year projections for the U.S. livestock sector and be used in relevant policy analysis.

Tables

Table 1. Prior Means for Meat Group

	Elasticity
Meat Price	-0.252
Income	0.343

Table 2. Prior Means for Total Demand Elasticities

	Beef	**Pork**	**Broiler**	**Turkey**	**Income**
Beef	-0.52	0.1	0.05	0.05	0.45
Pork	0.1	-0.45	0.05	0.05	0.35
Broiler	0.05	0.05	-0.35	0.05	0.25
Turkey	0.05	0.05	0.05	-0.35	0.25

Table 3. Prior Means for Conditional Demand Elasticities

	Beef	**Pork**	**Broiler**	**Turkey**	**Expenditure**
Beef	-0.962	-0.155	-0.186	0.001	1.312
Pork	-0.243	-0.648	-0.133	0.012	1.020
Broiler	-0.195	-0.092	-0.481	0.023	0.729
Turkey	-0.195	-0.092	-0.081	-0.377	0.729

Table 4. Meat Group Elasticities

	Elasticity
Meat Price	-0.217
Income	0.305

Table 5. Total Demand Elasticities

	Beef	**Pork**	**Broiler**	**Turkey**	**Income**
Beef	-0.348	0.134	0.007	0.185	0.398
Pork	0.062	-0.475	0.104	-0.012	0.304
Broiler	0.109	0.017	-0.280	-0.203	0.232
Turkey	-0.118	0.071	0.032	-0.110	0.202

*Elasticities from table 6 will be used in the model

Table 6. Conditional Demand Elasticities

	Beef	**Pork**	**Broiler**	**Turkey**	**Expenditure**
Beef	-0.807	-0.131	-0.238	0.134	1.303
Pork	-0.288	-0.677	-0.083	-0.051	0.994
Broiler	-0.159	-0.138	-0.423	-0.233	0.761
Turkey	-0.352	-0.064	-0.092	-0.136	0.662

Beef Equations

Table 7. Beef Cow Inventory – January 1, 1000 Head

Variable	Coefficient	S.E.
Intercept	-394.80	1085.80
lag(Beef Cow Inventory)	0.95**	0.03
lag(Heifers Kept for Replacement)	0.72**	0.12
lag(Cow Slaughter)	-0.70**	0.10

Table 8. Calf Crop – January 1, 1000 Head

Variable	Coefficient	S.E.
lag(Beef Cow Inventory + Dairy Cow Inventory)	0.89**	0.003

Table 9. Steers Larger Than 500 Pounds, 1000 Head

Variable	Coefficient	S.E.
Intercept	5548.39**	1089.20
lag(Net Calf)	0.29**	0.03

Table 10. Other Heifers Larger Than 500 Pounds, 1000 Head

Variable	Coefficient	S.E.
Intercept	6663.52**	2093.50
lag(Net Calf)	0.08	0.05
lag(Real Returns Cow-Calf)	-4.81**	1.22

Table 11. Heifers Larger Than 500 Pounds Kept for Beef Cow Replacements, 1000 Head

Variable	Coefficient	S.E.
Intercept	-310.03	1123.40
lag(Beef Cow Inventory)	0.18**	0.03
lag(Real Returns Cow-Calf)	3.20**	0.87
Lag2(Real Returns Cow-Calf)	1.31**	0.29

Table 12. Bulls Larger Than 500 Pounds, 1000 Head

Variable	Coefficient	S.E.
Intercept	557.06**	172.400
lag(Beef Cow Inventory + Dairy Cattle Inventory)	0.04**	0.004

Table 13. Calves Smaller Than 500 Pounds, 1000 Head

Variable	Coefficient	S.E.
Intercept	-10659.20**	2666.1
lag(Net Calf)	0.69**	0.07

Table 14. Federally Inspected Steer Slaughter, 1000 Head

Variable	Coefficient	S.E.
Intercept	-1005.61	1649.9
Steers Larger than 500 Pounds	0.87**	0.11
Calves	0.10*	0.04

Table 15. Federally Inspected Heifer Slaughter, 1000 Head

Variable	Coefficient	S.E.
Intercept	16559.00**	4510.50
(Other Heifers + Heifers Kept for Replacement)*FI Ratio	0.59**	0.12
Dairy Cow Inventory	-1.60**	0.33
Real Returns Cow Calf Producers	-4.12**	1.23
lag(Real Returns Cow Calf Producers)	-8.49**	1.27

Table 16. Federally Inspected Cow Slaughter, 1000 Head

Variable	Coefficient	S.E.
Intercept	2182.37	1667.90
(Beef Cow Inventory + Dairy Cattle Inventory)*FI Ratio	0.03	0.04
lag(Real Returns Cow Calf Producers)	-3.94**	0.92

Table 17. Federally Inspected Bull Slaughter, 1000 Head

Variable	Coefficient	S.E.
Intercept	-545.97**	169.900
(Beef Cow Inventory + Dairy Cattle Inventory)	0.03**	0.004

Table 18. Cattle Slaughter Weight, lbs.

Variable	Coefficient	S.E.
Intercept	682.08**	3.96
Time Trend	5.71**	0.23
Real Corn Price	-10.94**	2.31

Pork Equations

Table 19. Change in Sows Farrowing, 1000 Head

Variable	Coefficient	S.E.
Intercept	4.92	70.65
Lag(Real Net Returns Hogs)	19.82	11.92
Lag2(Real Net Returns Hogs)	19.01	11.74

Table 20. Federally Inspected Barrow and Gilt Slaughter, 1000 Head

Variable	Coefficient	S.E.
Intercept	-2164.62	3466.70
Pig Crop * FI Ratio	0.96**	0.03

Table 21. Federally Inspected Sow Slaughter, 1000 Head

Variable	Coefficient	S.E.
Intercept	-1054.33	1672.40
Sows Farrowing * FI Ratio	0.37*	0.15

Table 22. Federally Inspected Boar Slaughter, 1000 Head

Variable	Coefficient	S.E.
Intercept	-2107.93*	827.60
Sows Farrowing	0.22**	0.07

Table 23. Pigs per Litter

Variable	Coefficient	S.E.
Intercept	7.74**	0.081
Time Trend	0.09**	0.005

Table 24. Hog Slaughter Weights, lbs

Variable	Coefficient	S.E.
Intercept	179.74**	0.817
Sows Farrowing * FI Ratio	1.20**	0.046

Broiler Equations

Table 25. Broiler Hatchery Supply Flock, 1000 head

Variable	Coefficient	S.E.
Lag(Broiler Hatchery Supply Flock)	1.012**	0.006

Table 26. Broiler Chicks Hatched , 1000 head

Variable	Coefficient	S.E.
Intercept	1925899.00**	443907.00
(Broiler Hatchery Supply Flock) X (Eggs per Layer)	0.55**	0.04
Broiler Real Net Returns	7275.71	7926.00
Time Trend	27658.00**	3820.10

Table 27. Broiler Slaughter, 1000 head

Variable	Coefficient	S.E.
Intercept	-13938.90	86428.70
Broiler Chicks Hatched	0.94**	0.01

Table 28. Average Dressed Weight of Broilers, lbs

Variable	Coefficient	S.E.
Intercept	3.06**	0.015
Time Trend	0.06**	0.001

Turkey Equations

Table 29. Eggs in Incubators, 1000 eggs

Variable	Coefficient	S.E.
Intercept	447421.30**	10865.20
Lag(Real Net Returns Turkey)	1664.99*	597.90
Time Trend	-5510.99**	798.80

Table 30. Net Poults Placed, 1000 head

Variable	Coefficient	S.E.
Intercept	66852.86**	10248.80
Eggs in Incubators	0.61**	0.03

Table 31. Turkey Slaughter, 1000 head

Variable	Coefficient	S.E.
Intercept	7623.15	14695.30
Net Poults Placed	0.86**	0.05

Table 32. Dress Weight Turkey, lbs

Variable	Coefficient	S.E.
Intercept	16.74**	0.132
Time Trend	0.32**	0.008

Price Equations

Table 33. Change in Boxed Beef Price, $/cwt

Variable	Coefficient	S.E.
Intercept	-0.51	0.83
ΔRetail Beef Price	0.41**	0.04

Table 34. Change in Cow Carcass Price, $/cwt

Variable	Coefficient	S.E.
Intercept	-1.01	1.58
ΔRetail Beef Price	0.50**	0.08

Table 35. Change in Steer Price, $/cwt

Variable	Coefficient	S.E.
Intercept	-0.22	0.24
ΔBoxed Beef Price	0.67**	0.02

Table 36. Change in Heifer Price, $/cwt

Variable	Coefficient	S.E.
Intercept	-0.23	0.25
ΔBoxed Beef Price	0.68**	0.03

Table 37. Change in Cow Price, $/cwt

Variable	Coefficient	S.E.
Intercept	-0.25	0.39
ΔCow Carcass Price	0.37**	0.02

Table 38. Change in Feeder Steer Price, $/cwt

Variable	Coefficient	S.E.
Intercept	-0.23	0.696
ΔSteer Price	1.66**	0.103
ΔReal Feed Cost	-0.27*	0.105

Table 39. Change in Barrow and Gilt Price, $/cwt

Variable	Coefficient	S.E.
Intercept	-0.62	0.77
ΔRetail Price of Pork	0.25**	0.05

Table 40. Change in Broiler Price, Cents/lb

Variable	Coefficient	S.E.
Intercept	0.11	0.54
ΔRetail Price of Broilers	0.58**	0.08

Table 41. Change in Turkey Price, Cents/lb

Variable	Coefficient	S.E.
Intercept	0.17	0.67
ΔRetail Price of Turkey	0.39**	0.10

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Appendix A. Data Sources

Cattle Sector

Cattle inventory data comes from the annual January 1 Cattle report issued by the USDA-NASS. Included variables are:

-Beef Cow Inventory

-Calf Crop

-Steers Larger than 500 Pounds

-Other Heifers Larger than 500 Pounds

-Heifers Larger than 500 Pounds Kept for Beef Cow Replacements

-Bulls Larger Than 500 Pounds

-Calves Smaller Than 500 Pounds

All cattle slaughter data comes from monthly USDA-NASS slaughter reports. The annual value used is a yearly sum of the monthly data. Included variables are:

-Federally Inspected Steer Slaughter

-Federally Inspected Heifer Slaughter

- Federally Inspected Cow Slaughter

- Federally Inspected Bull Slaughter

Cattle carcass slaughter weights are from the monthly NASS slaughter reports. The variable is calculated by dividing total commercial beef production by total commercial slaughter.

Pork Sector

Hog inventory data comes from the USDA-NASS Quarterly Hogs and Pigs report. Variables included are:

-Sows Farrowing

-Pig Crop

-Pigs per Litter

Hog slaughter data comes from weekly USDA-NASS slaughter reports. Variables included are:

-Federally Inspected Barrow and Gilt Slaughter

-Federally Inspected Sow Slaughter

-Federally Inspected Boar Slaughter

-Federally Inspected Weights Hogs

Broiler Sector

Inventory data for the broiler sector come from the USDA-NASS Chicken and Eggs monthly report. Broiler slaughter and weights come from the monthly USDA-NASS Poultry Slaughter Report.

Turkey Sector

Inventory data for the turkey sector comes from the USDA-NASS Turkey Hatchery report. Variables included are:

-Eggs in Incubators

-Net Poults Placed

Turkey slaughter and weights data comes from the monthly USDA-NASS Poultry Slaughter Report.

Prices

Barrow and Gilt Price - Broiler Price (1990-2012) - USDA Economic Research Service. Livestock Prices. National base 51 – 52% lean. https://www.ers.usda.gov/data-products/livestock-meat-domestic-data/

Boxed Beef Price – USDA Agricultural Marketing Service. Report LM_XB403. National Daily Boxed Beef Cutout and Boxed Beef Cuts. Choice 600-900 Current Cutout Values.

Broiler Price (1990-2012) - USDA Economic Research Service. Wholesale Prices. 12-City Composite. https://www.ers.usda.gov/data-products/livestock-meat-domestic-data/

Broiler Price (2013-2017) - USDA Economic Research Service. Wholesale Prices. National Composite. https://www.ers.usda.gov/data-products/livestock-meat-domestic-data/

Cow Price – USDA Economic Research Service. Livestock Prices. Slaughter Cow Price. Boning Utility. Sioux Falls. https://www.ers.usda.gov/data-products/livestock-meat-domestic-data/

Cow Carcass Price – USDA Economic Research Service. Wholesale Prices. Beef Central U.S. Boneless beef, 90% fresh. https://www.ers.usda.gov/data-products/livestock-meat-domestic-data/

Heifer Price – USDA Agricultural Marketing Service. Report LM_CT180. 5 Area Weighted Average Direct Slaughter Cattle. Live Basis Heifers. Total all grades.

Retail Beef Price – USDA Economic Research Service. Historical Price Spread Data for Beef and the All-Fresh Beef Price. Retail Value (F). https://www.ers.usda.gov/webdocs/DataFiles/52160/history.xls?v=42781

Retail Chicken Price – U.S. Bureau of Labor Statistics. Chicken, fresh, whole, per lb. U.S. city average. Series ID: APU0000706111. http://data.bls.gov/cgi-bin/srgate

Retail Pork Price - USDA Economic Research Service. Historical Price Spread Data for Pork. Retail Value (F). https://www.ers.usda.gov/webdocs/DataFiles/52160/history.xls?v=42781

Retail Turkey Price – U.S. Bureau of Labor Statistics. Turkey, frozen, whole, per lb. U.S. city average. Series ID: APU0000706311. http://data.bls.gov/cgi-bin/srgate

Steer Price - USDA Agricultural Marketing Service. Report LM_CT180. 5 Area Weighted Average Direct Slaughter Cattle. Live Basis. Steers. Total all grades.

Turkey Price - USDA Economic Research Service. Wholesale Prices. Hens, 8-16 lb. https://www.ers.usda.gov/data-products/livestock-meat-domestic-data/