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Growing Biofuel Demands and Implications for Livestock Feed Costs

The relationship between complete-feed prices and commodity feedstock prices are estimated to analyze the effect of higher commodity prices on feed costs, with particular attention towards the price effects and substitutability of corn distillers dried grains with solubles (DDGS). Assuming the historical positive correlation between corn and DDGS prices, each $1/ton increase in the price of corn increases per ton feed costs between $0.45 and $0.67 across livestock sectors. A negative price correlation would offset some of the cost increases, but under most scenarios feed costs are expected to be at or above those experienced in 2007.

Key Words: biofuels, commodity prices, distillers dried grains with solubles, livestock feed costs

Introduction

An expanding U.S. biofuels industry and corresponding increased demands for grains and oilseeds is affecting the structure of agricultural commodity markets. While the demand from biofuels processors are a well-known, though still relatively recent factor affecting prices, growing incomes and populations in China and India have also increased the demand for farm commodities. The growing demands, relative to available supplies, is significantly raising the average level of commodity prices, as well as increasing variability. These structural changes have substantially different implications for crop and livestock operations. While higher grain prices may provide some opportunities to expand cash crop production, for livestock producers, management adjustments will be required to respond to higher and more variable feed costs and to take advantage of supplies of alternative energy by-product feeds.

The dramatic increase in commodity prices, particularly corn, from 2006 to 2007 translated into feed cost increases in the Northeast U.S. of 12.7%, 16.8%, 17.0%, and 18.4%, for the hog, layer, broiler, and dairy livestock sectors, respectively (USDA). Given the expectation that corn and soybean meal (SBM) prices will remain high (and highly variable), substantial interest exists in evaluating the outlook for livestock feed prices and the increased availability of biofuels by-products as feed ingredients. While the potential increased supplies of biofuels-related by-product feeds may provide a lower-priced feed ingredient, several limitations and barriers will need to be addressed to minimize the impact of increased commodity prices. The ultimate effect on overall feed costs will vary by livestock sector, given varying feedstock prices and the degree of feasible ration adjustments. Ration adjustments will be limited by nutritional constraints, nutrient management implications, and availability of a quality product.

Recent research has effectively utilized large simulation and input-output models to investigate the effects of various biofuels production scenarios on grain and related markets (e.g., Elobeid, et al., English, et al., FAPRI (2005, 2007), and Swenson and Eathington), but a closer inspection of the underlying technical relationships between input prices and feed costs is needed to better understand the underlying component effects. Using historical commodity price and feed cost data in the Northeast, we estimate these technical relationships and examine the changes feed cost effects over a range of anticipated future prices. Understanding the differential impacts across livestock sectors will help illustrate limitations on feasible ration adjustments in relation to current utilization and potential impacts on profitability across sectors.

Similarly, Ferris utilized an econometric approach to measure the impact and utilization of corn grain and SBM in a period of rapidly expanding by-product feed supplies from ethanol production, and predicted continued downward pressure in corn distillers dried grains with solubles (DDGS) prices for the next ten years. In his approach, feeds were converted into protein and energy equivalents and synthetic prices were estimated from prices for corn and soybean. Prices for ethanol by-product feeds were then generated based on the feed composition and the computed synthetic energy and protein prices. While Ferris was able to demonstrate the substitution of ethanol by-product feeds on a nutritional basis, it was not related back fully to overall feed costs or differential impacts by livestock sector.

This paper focuses on the direct relation of input prices to feed costs whereby models are specified and estimated for the technical relationships between ingredient prices and feed prices for various livestock sectors in the Northeast. In so doing, these relationships encompass both the impacts of relative price changes in feed components and nutritional substitutability. Then, given the statistical estimates of these macro-relations, alternative potential increases in commodity prices are used to estimate the potential effect on feed costs. Prices of futures contracts for corn and soybean meal are used a source of expected price changes. We also utilize long-run projections of commodity and feedstock prices from FAPRI (2007) to estimate long-run price correlations for DDGS and other feedstocks. Given an uncertain future, such information can serve as a useful tool for planning production and feeding decisions, as well as the adoption of appropriate risk management strategies related to controlling variation in input costs.

We start with a brief primer on recent biofuels industry developments, followed by a description of our feed-cost modeling framework and empirical specifications. Then the data used, econometric results, and model simulations are described. We close with some summary conclusions and directions for future research.

Biofuels Industry Development

The Renewable Fuels Association (RFA) reported that 131 corn-based fuel ethanol plants were in production in the U.S. as of October 2007, with a capacity of 6.9 billion gallons per year. Another 83 were under construction or expanding and, if completed as planned, would add another 6.6 billion gallons of capacity (RFA). From 2002 to 2007, U.S. ethanol production has increased nearly 40% each year. Since one bushel of corn produces about 2.8 gallons of ethanol, these plants represent a significant demand for corn.

Biodiesel processing, while at an earlier industry stage of development, currently is occurring at 105 plants in the U.S., with production capacity of 864 million gallons per year (National Biodiesel Board, NBB). Another 85 plants are under construction or expanding that would add 1.7 billion gallons of capacity. U.S. biodiesel sales increased from 75 million gallons in 2005 to 250 million gallons in 2006, a 133% increase (NBB). Plants primarily utilize soybean oil as the oil input, implying related feed-market effects through soybean and soybean meal price adjustments. These adjustments are concurrent to those already experienced in corn markets.

Corn ethanol and biodiesel facilities are no longer confined to the Corn Belt. Plant development is proposed and/or ongoing in such states as WA, CA, GA, and NY, to name a few. Three ethanol plants with a combined production capacity of 215 million gallons per year (mgy) of ethanol are moving forward with development and construction plans in NY, and another 50 mgy plant began operations in late 2007. Combined, these plants will require 107 million bushels (mbu) of corn. Planned local sourcing of corn represents 200,000 acres, or 37% of the 2007 reported harvested acres of corn for grain in NY.

Similarly, two biodiesel plants are expected to produce a combined 10 mgy of biodiesel requiring around 4.8 mbu of soybeans for required oil feedstocks. While the anticipated amount of local crop sourcing is not available, the feedstock acreage equivalent based on 2007 NY harvested acres of soybeans is in excess of 50%. The point is this, such upcoming local demands for corn and soybeans will result in additional impacts on local prices and price variability.

Model Framework and Data

The prices of four complete livestock feeds for the Northeast U.S. are plotted against years in figure 1 (see the data section for a precise definition of these prices). These (nominal) prices clearly have trended upward over the last 22 years, and the year-to-year changes have some correlation. Presumably, these correlations are related importantly to the common influences of ingredient costs. Corn prices are perhaps the single most important driver of feed costs, but related ingredient prices also contribute to the correlations.

Our analysis of the relationship between ingredient and feed prices is based on a cost framework. The price of a feed (say in dollars per ton) can be decomposed into its cost components and a profit margin. If complete information were available for all components on the right-hand side, then an identity would exist at any point in time; however, such information is unavailable, particularly for changes over time. For example, suppose the price of a mixed feed (FP) at a particular point in time depends on the prices of two commodity inputs (YP and XP), and assuming Y and X are used in a 0.6 and 0.4 proportion (with all prices in the same units, say per ton), then for a point in time, FP = 0.6YP + 0.4XP. If this is known, then no estimation is required. But, in practice, the right-hand side is more complex, and the technical coefficients may vary with the price levels.

In this context, regression models can provide insights into the price relationships. The regression approach also permits a comparison of impacts of higher commodity prices across livestock sectors and an estimation of future feed prices conditional on possible future ingredient costs. Basically, the models attempt to capture the effects of the changes in major cost components on feed prices, with the omitted costs captured by a trend variable and the residual.

Specifically, we use historical prices for representative complete mixed-feeds disaggregated by livestock sector and the principal commodity inputs in the Northeast region and estimate their technical relationships.[1] The availability of ethanol by-products as potential feedstocks, primarily DDGS, will be considered in relation to substitutability of other feedstock products, in terms of both energy and protein requirements. Consider the following representative model:

(1) $$PFEED_{i,j,t} = f\left(PCOMM_{i,j,t-}, PINGR_{i,j,t-} \middle| \theta_{i,t-}\right) + \varepsilon_{i,j,t} ,$$

where $PFEED_{i,j,t}$ is the complete feed cost in region *i*, livestock sector *j*, and April of year *t*. Our focus was on the Northeast region of the U.S. (i.e., the New England states, NY, PA, NJ, DE, and MD) as feed prices are reported regionally by USDA. Complete feed price quotes are available for dairy, market hogs, broilers, and layers. $PCOMM_{i,j,t-}$ is the price of the main commodity input (e.g., corn), for sector *j* in region *i*. One or more month lags (*t*-) are considered to account for the survey time period and feed manufacturing time from feedstock procurement. Similarly, $PINGR_{i,j,t-}$ reflects other feed ingredient components (e.g., soybean meal, DDGS, and meat and bone meal). $\theta_{i,t-}$ represents other lagged input costs into the production of feeds such as labor. A linear trend variable is included as an expedient to capture the effects that are causing feed prices to adjust, net of ingredient price changes. Finally $\varepsilon_{i,j,t}$ is the error term with mean zero for all sectors *j*, variance σ_j^2, and covariances across equations of $\sigma_{j,k}\ \forall\ j \neq k$.

The ingredient prices included in the model are based on our judgment and consultation with animal nutritionists about the importance of the particular commodities in manufacturing the various feeds in the Northeast. The difference in livestock sectors is important given that DDGS feed ingredients can be utilized more readily in ruminant rations than in non-ruminant rations. While the set of ingredients reflects the major feedstock components to livestock rations in the Northeast, DDGS also represents a by-product produced from corn ethanol dry milling, and expanded biodiesel production from soybean oil implies a larger crush and meal supply.

Three alternative functional forms (linear, semi-log, and inverse) were considered for their overall statistical fit and flexibility in allowing the marginal effects on feed prices to vary with the level of ingredient prices. Such a model framework allows us to derive technical feed cost relationships that can change continuously with the cost of the respective input. A hypothesis is that a curvilinear form is preferable, because as prices increase for one ingredient, feed manufacturers will shift to lower-cost alternatives. Also, since we wish to make estimates of the effects of high corn prices (near or beyond the upper range of prices in the data set), the functional form is important because of the marginal effects will differ among functional forms at the data extremes.

Generally, for the semi-logarithmic form (e.g., $Y = b_0 + b_1 \ln X$), the estimated marginal effect is b_1/X, where b_1 is the estimated slope parameter and X is the value of the explanatory variable at which the marginal effect is being evaluated. If b_1 is a positive constant, as assumed in the model, then as X increases, the marginal effect declines. Similarly, the marginal effect for the inverse form (e.g., $Y = b_0 + b_1 X^{-1}$) is the negative of parameter b_1, divided by the square of associated regressor, X.

The variables used in the regression models are summarized in table 1. The data set covers the years 1986 through 2007. All of the prices are in current dollars per ton. April complete feed prices were taken from *Agricultural Prices* (USDA). Complete feed prices are collected annually during April using farm establishment surveys and are an average for the Northeast region. The commodity input and feed ingredient prices were obtained from the weekly magazine *Feedstuffs* and are wholesale prices free-on-board (FOB) Buffalo, NY. We use a weekly (five day) average for the second week in March. Input prices were also obtained for additional lagged months, January and February, but since the additional lags were not statistically important in preliminary specifications, results are reported only for the March to April lag. By comparing the relative coefficient of variation values (CV), DDGS demonstrated the lowest relative variation in prices, but all commodities were relatively similar.[2]

Model Estimation

Equations were first fitted by Ordinary Least Squares (OLS) using the three alternative functional forms. However, since the regressors are somewhat different in the four equations, it makes statistical sense to fit the four equations as a system of seemingly unrelated regressions (SUR).[3] A chi-square test supports the use of SUR, but the estimated coefficients are quite similar for the two estimators.[4] The equations have good statistical fits, with corrected R-squared coefficients near or above 0.8 (table 2).

As mentioned above, the marginal effects of changes in ingredient prices are expected to vary as their prices vary. Given our interest in estimating feed costs for future corn prices that will arguably be at or above historical price levels, the marginal effects at the price extremes are particularly salient. The restrictive linear functional form (without interaction effects) does not allow for such variation, while the semi-log and inverse forms do provide us with declining marginal effects as prices rise.

While both curvilinear forms slightly under-estimated feed costs at the higher end of corn prices, the semi-log model's marginal effects declined more slowly as prices rose. In addition, within-sample root mean square errors (RMSE) were lower for all equations with the semi-log functional form, and the model objective function value (-lnLikelihood) is minimized for the semi-log model, although the results are similar for the three alternatives.[5]

The trend variable is the statistically most important variable in the equations, which likely captures a collection of important costs such as energy and labor that are moving upward and are highly correlated. Durbin-Watsin test statistics reveal non-rejection of the null hypothesis that the residuals uncorrelated.[6] Excluding the trend variable resulted in negative coefficient estimates, particularly for DDGS, implying negative marginal feed cost effects and in contrast to our *a priori* hypothesis that marginal feed costs should be non-negative.[7]

Note, changes in broiler prices are unaffected by changes in DDGS prices, as the broiler equation does not contain DDGS as a feedstock ingredient. Original model specifications showed lack of significance and incorrect signs, so the variable was removed. This is consistent with industry practices where poultry broiler operations use very little, if any, DDGS, while its use in layer operations is more common, although still limited.

The relative size and significance of the various input ingredients will be affected, in part, by the relative contributions of the ingredients to their complete rations. In particular to ruminants, the ratio of corn to SBM used will vary depending on the proportions of corn silage forage (lower) and hay forage (higher) fed. Higher levels of hay forages fed increases protein contributions to the diet and thereby lowering the requirement of SBM fed. Hog rations are generally similar in corn to SBM ratios as a mixed corn silage and hay forage dairy diet, but finisher rations tend to be hotter (higher corn proportion) than that of grower pigs. Poultry rations typically exhibit somewhat lower corn to SBM ratios than hogs, and roasted soybeans as opposed to SBM is commonly fed.

As expected, the price of corn is the statistically most important ingredient driver of feed costs, with other ingredient prices having varying importance depending on the particular feed. In the hog and layer feed equations, the soybean meal estimates were not statistically different from zero, but the DDGS estimates were (particularly for hogs). This is due, in part, to primary ration components described above. However, in all equations, the estimated marginal price effects for DDGS are greater than that for SBM. This is likely due, in part, to the fact that DDGS can substitute some for SBM as a protein supplement, as well as for corn grain given its relatively high fat (energy) content.

The coefficients are estimates and are influenced by the range of input prices and correlation among prices. While the ranges in prices are relatively wide for all inputs, corn grain and soybean meal in particular have maximum levels in the sample that are below prices currently being experienced. Price correlations, however, are reasonably modest with corn price correlations below 0.50 with all other ingredients. Soybean meal price correlations with DDGS and MBM are higher (0.66 and 0.74, respectively), which is expected given increased substitution as protein sources. The higher the multicollinearity, the greater the potential difficulty in partitioning out the individual effects of the independent variables, but multicollinearity does not appear to be serious within the models estimated.[8] Breusch-Pagan test statistics were computed to test for the presence of heteroskedasticity in the residuals and the Chi-square test statistics indicate the null hypothesis of no heteroskedasticity cannot be rejected at the 95% confidence level for all equations.[9]

Model Simulations

To evaluate the potential impact on livestock feed costs from increasing commodity prices, the estimated model was simulated over a range of possible future prices and assumed price correlation relationships. March 2007 commodity prices for the Northeast U.S. are used as the base price levels, and price increases of 10%, 25%, and 50% for corn and SBM are evaluated. Relative to 2007, futures contract trading early in 2008 show corn prices consistently above $5.50/bushel and SBM prices above $330/ton, approximately 50% above the 2007 levels, so our range in expected price changes are reasonable. Given these unprecedented price levels, the market clearly expects that future demands are going to be difficult to balance with supply.

While DDGS have been used in livestock rations for many years, the supply of DDGS has been small. Thus, it is not surprising that historical movements in DDGS prices have tracked corn prices. The correlation coefficient between these two price series over the sample period was 0.45. Corn and SBM prices have also been positively correlated; over the sample period this correlation was 0.50. If corn and DDGS and corn and SBM prices continue to be positively correlated as recent history depicts, then increases in corn prices would result in increases in the prices of DDGS and SBM.[10]

Whether or not these historical correlations will continue depends on the growth in supplies relative to demand. Increasing demands for corn and, with it, increasing corn prices, have affected acreage allocations for various commodities. Recent shifts in corn acreage, primarily at the expense of soybeans, have increased soybean and SBM prices. The expected future price correlation between corn and SBM was estimated based on future price predictions in FAPRI (2007). Predicted annual crop year ingredient prices were collected for corn grain, SBM, and DDGS for the 2006/2007 through 2016/2017 crop years. Over this time horizon, the computed price correlation coefficient between corn and SBM is 0.97, significantly above that exhibited in the historical sample data.

The dramatic growth in ethanol production is resulting in a larger supply of DDGS; each bushel of corn used in ethanol production produces about 17 pounds of DDGS. Larger supplies of DDGS, relative to demand, are expected to reduce its price and, therefore, make it a relatively more preferable feed ingredient, but its use is limited by nutritional constraints. If DDGS prices do drop, then the price correlation between it and corn could decline and become negative. The estimated future price correlation between corn and DDGS is -0.82, based on FAPRI (2007). Clearly, their projections anticipate a significant negative price relationship will develop between corn and DDGS. We explore the impacts of these alternative price correlation relationships on marginal and predicted feed costs below.

Marginal (Point) Effects

To begin, we focus on corn prices, and estimate marginal feed cost effects at the three price levels (i.e., percentage changes) assumed above. The predicted marginal feed costs, assuming historical positive price correlations, are displayed in table 3 under the S1 (Scenario 1) columns. At 2007 baseline prices, dairy and broiler feeds have the highest marginal effects, 0.59 and 0.67, respectively, implying that at the base levels a one dollar per ton increase in the price of corn results in a 59 (67) cent per ton increase in the price of dairy (broiler) feed. This is consistent with the fact that common dairy and broiler feeds use the higher relative contributions of corn in their complete feed rations, even though cattle, as a ruminant, are expected to be more able to use DDGS in their rations. The relative cost increases are also consistent with the percentage changes in reported feed costs from 2006 to 2007 that showed feed costs for dairy and broilers increased relatively more than for hogs and layers (USDA).

The marginal effects for hogs and layers were 0.50 and 0.45, respectively, at 2007 price levels. As corn prices rise, the marginal effects decrease, consistent with the semi-log functional form and the expectation that as prices increase for one ingredient, feed manufacturers and producers will shift to lower-cost alternatives. For example, marginal feed costs for dairy with respect to corn prices drop from 0.59 at the base 2007 prices to 0.39 when corn prices increase 50%. Based on the computed 90% confidence intervals, the reductions in marginal feed costs with respect to corn prices from 2007 base prices are statistically different from zero when corn prices increase beyond 10%.

Marginal feed costs assuming the anticipated future price correlation relationships are shown under the Scenario 2 (S2) columns (table 3). Marginal feed costs, evaluated at base levels, are reduced (per ton) by $0.19, $0.23, and $0.39 for layer, dairy, and hog feeds, respectively. Opportunities for feed cost savings are increased with ration adjustments towards more DDGS. Cost savings occur with the negative DDGS relation, but the higher positive correlation of the corn and SBM relations offsets a portion of those savings.

Interestingly, the proportional reductions in marginal feed costs, assuming a negative correlation between DDGS and corn prices, are higher for hog and layer feeds (78% and 44%, respectively) than for dairy feed (39%). This appears to be counter-intuitive given that, nutritionally, nonruminants are expected to be less able to substitute DDGS into their existing rations. Both the hog and layer equations have relatively lower estimated technical feed cost coefficients for SBM which are not statistically different from zero. Note, however, while relative prices and the nutritional feasibility to incorporate DDGS into livestock rations are factors determining the technical coefficients, the relative proportions of ingredients in rations varies by livestock feed and will also affect the changes in estimated feed costs. In addition, the estimated technical coefficients reflect the historical utilization of these ingredients that may be different than that expected with increasing supplies in the future. Also, given the computed 90% confidence intervals under the S2 scenario, the reductions in marginal feed costs from the 2007 base levels are not significantly different from zero (i.e., the confidence intervals overlap) for the hog equation and only significantly different for the layer equation when prices increase by 50% or more.

The differences in marginal effects across price correlation scenarios are non-trivial. At all price levels and for all livestock sectors, the changes in marginal feed costs with respect to corn prices are statistically different for all price correlation scenarios. Marginal feed costs with respect to corn prices actually increase for broiler feed due to the fact that DDGS is not included in the broiler equation and the positive price correlation between corn and SBM increases in magnitude between the historical (S1) and future (S2) correlation scenarios.

Predicted Effects

While the foregoing estimates are useful, particularly in understanding the short-run effect of increased corn prices, feed-based commodities are concurrently experiencing increasing price volatility and significant upside movements. Thus, we evaluate the impact on feed costs of concurrent increases in corn and SBM prices, while still isolating the potential feed cost savings from DDGS price movements (table 4).[11] Given various corn-SBM price changes, the estimated percentage changes in feed costs are shown in table 4. Under the historical DDGS pricing relationship (Scenario 1) feed cost increases are expected to range from 5% to 17% for dairy and broilers, and 4% to 12% for hogs and layers.

Analogously, Scenario 2 shows the estimated feed cost changes when the negative price correlation exists between corn and DDGS (table 4). The estimated (mean) cost changes are with feed costs ranging from 3% to 7% for dairy, 2% to 5% for layers, and -0.5% to 3% for hogs. For a given SBM price, increases in corn prices increase potential DDGS cost savings; i.e., DDGS can substitute more for corn (for energy) with SBM becoming relatively more expensive as a protein source. However, for a given corn price, increases in SBM prices reduce the potential DDGS cost savings; i.e., while DDGS can also substitute for SBM (for protein), DDGS's higher fat levels (energy) limits its additive effect for protein as excessive fat reduces production (e.g., milk or meat), and protein becomes more limiting in DDGS-included rations.

Regardless of the pricing levels, feed costs for dairy and layers are still expected to increase, but are ameliorated by the DDGS price adjustments. Cost changes for hog feed shows reductions in overall feed costs for the upper levels of corn prices as long as SBM meal prices remain low, but these savings are lost more quickly as SBM prices increase. While the hog and layer feeds show lower price effects relative to dairy, as corn and SBM prices increase, the relative cost savings to dairy increase (i.e., the gap widens), likely reflecting additional substitutability of DDGS when prices increase.

Perhaps more generally useful, the results in table 4 may be viewed as upper and lower bounds of expected changes in feed costs given either pessimistic (Scenario 1) or optimistic (Scenario 2) market price relationships. Additionally, given that the semi-log model underestimated actual feed cost effects at higher ingredient prices, the conditional forecasts at the price extremes are more likely underestimating than overestimating the effects on feed costs.

Conclusions

Increasing commodity prices fueled by biofuels production growth appear to be a boon to the nation's crop farmers, at least in the short run, but such price changes affect the level and variability of feed costs to the nation's livestock producers. These higher feed costs, in turn, will impact production levels and profitability for livestock producers. A statistical model describing the technical relationships between feed ingredient prices and feed costs was estimated for the Northeast U.S. for four livestock sectors.

As expected, changes in corn prices were found to be the primary ingredient driver of feed costs. Evaluated at 2007 prices and assuming the historical price relationship between corn and DDGS, each $1/ton increase in the price of corn increases per ton feed costs by $0.59, $0.50, $0.67, and $0.45 for dairy, hogs, broilers, and layers, respectively. As corn prices increase, the marginal feed cost effects decrease, consistent with the expectation that as prices increase for one ingredient, feed manufacturers and producers will shift to lower-cost alternatives.

Assuming that corn and DDGS prices will become negatively correlated, the estimated marginal feed cost effects with respect to corn price are $0.36, $0.11, $0.85, and $0.26 for dairy, hogs, broilers, and layers, respectively. That is, a lower DDGS price would offset some of the other cost increases, but under most scenarios feed costs are still expected to be at or above those experienced in 2007. This is particularly salient given that livestock feed costs in 2007 were significantly above those realized one year earlier.

In evaluating changes in feed costs across a range of corn and SBM prices, initial cost increases were somewhat higher for dairy feeds than for hog and layer feeds. While nutritionally DDGS can be substituted in higher proportions in ruminant rather than non-ruminant rations, offsetting costs are also affected also by relative proportions of corn and SBM in base rations and differences in historical utilization of DDGS across sectors. However, while the hog and layer feed costs had overall lower price effects, as prices increased for corn and SBM, DDGS cost savings were higher in the dairy rations. In addition, for all livestock sectors, DDGS cost savings increased as corn prices increased and decreased with increases in SBM prices, reflecting differences in DDGS substitutability in feed rations for energy and protein components.

The simulation estimates presented here are point estimates from the estimated parameters and conditional on a set of assumptions about future ingredient prices. Sampling error becomes particularly salient given that the forecasts are beyond the range of the sample data, with further distances from the mean implying larger confidence intervals around the point estimates. Structural changes in feed markets are also occurring given biofuels industry growth. The estimated technical relationships are likely to change over time with a consistent and growing supply of corn DDGS feedstocks and improvement in their nutritional quality. Updating the model estimates with additional data encompassing these new market conditions will be important to ascertain future impacts on livestock sectors. In addition, extending the model to other regions would be useful to determine regional impacts, conditional on spatial differences in agricultural production, ingredient pricing, and biofuels production.

Footnotes

[1] While becoming less common in livestock production enterprises, historical feed costs are available for "complete feeds"; i.e., feeds supplying energy, protein, and vitamins/minerals. It is perhaps more common today to work with "protein supplements" at high overall crude protein and to purchase and blend other feed ingredients at the farm. As we are considering changes in prices for both energy and protein needs, complete feed costs were utilized here.

[2] The coefficient of variation is the ratio of the standard deviation to the mean and measures the relative variability in data series with different means. The higher the coefficient of variation, the greater is the relative variability.

[3] The full set of OLS and SUR regression results are available upon request. Given the similarities in results across models, and for sake of brevity, we include only the one model.

[4] A SUR Chi Square test (p. 456, Judge, et al., 1988) that the error terms across equations were not correlated (H_o: $\sigma_{ij} = 0$ for $i \neq j$) was rejected at the 5% significance level for all functional forms (i.e., test statistics of 16.58, 22.12. and 30.39 for the linear, semi-log, and inverse functional forms, respectively). The test statistic, $\lambda = T\sum_{i=2}^{M}\sum_{j=1}^{i-1} r_{ij}^2$ where r_{ij}^2 is the squared correlation, and under H_o has an asymptotic χ^2 distribution with (*M*(M-1)/2) degrees of freedom, where *M* equals the number of equations, and a critical value of 12.59.

[5] RMSE = Percentage root mean square error = $100\sqrt{\frac{1}{N}\sum_{j=1}^{N}\left(\left(\hat{y}_j - y_j\right)/y_j\right)^2}$, where *N* is the number of observations, y_j is the actual data value, and $\hat{y}_j$ is the predicted data value. RMSE statistics are 3.33, 4.19, 7.09, and 4.61 for the semi-log model and 3.76, 4.28, 7.54, and 5.01 for the inverse model for the dairy, hog, broiler, and layer equations, respectively.

[6] DW test statistics were 1.33, 1.53, 1.85, and 1.82 for the dairy, hog, broiler, and layer equations, respectively – all within the inconclusive range of serial autocorrelation (N = 22).

[7] Correlation coefficients of the trend term with commodity prices were modest, ranging from -0.39 for DDGS to 0.26 for corn.

[8] Variance Inflation Factors (VIF) computed for each feed cost equation were 2.20, 2.20, 1.58, and 2.57 for the dairy, hog, broiler, and layer equations, respectively. Given the model specification, VIF's below 10.0 suggest that multicollinearity is not a serious issue.

[9] P-values of chi-square test statistics rejecting the null hypothesis were 0.87, 0.20, 0.75, and 0.48, for the dairy, hog, broiler, and layer equations, respectively.

[10] For the forthcoming model simulations, we assume the price of DDGS (PD_t) in time period t can be expressed as $PD_t = \left[1 + \rho\left(\left(PC_t - PC_{t-1}\right)/PC_{t-1}\right)\right] \times PD_{t-1}$, where PC is the price of corn

grain, and ρ is the computed price correlation coefficient. Analogous calculations are made with soybean meal and its estimated correlation coefficient.

[11] Given that the price scenarios reflect changing prices, presumably over a period of time, we increase the trend variable one unit, in addition to the respective price changes.

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Table 1. Northeast U.S. livestock feed costs and ingredient prices ($/ton), 1986 – 2007

Variable	Mean	Std. Dev.	Min.	Max.	CV
	------------------------- $ per ton -------------------------				
Livestock Feed Costs					
Dairy Feed (18% CP)	196.64	23.92	156.00	259.00	0.12
Hog Feed (14% - 18% CP)	233.00	35.44	172.00	330.00	0.15
Broiler Feed	245.95	40.51	188.00	336.00	0.16
Layer Feed	213.59	30.33	164.00	288.00	0.14
Feed Ingredient Prices					
Corn Grain (#2, Yellow) [a]	100.43	19.09	62.00	147.00	0.19
Soybean Meal (49% CP)	206.71	38.90	146.00	301.00	0.19
DDGS	130.68	22.06	88.00	167.00	0.16
Meat and Bone Meal	218.91	39.76	150.00	300.00	0.18

Sources: Livestock feed costs represent April complete feed costs for the Northeast U.S., (USDA). Feed ingredient prices represent mid-month March Buffalo wholesale market prices, FOB (*Feedstuffs*), DDGS = Distillers Dried Grains with Solubles.

[a] Corresponding corn prices in dollars per bushel are: mean 2.81, minimum 1.74, and maximum 4.12.

Table 2. Livestock feed cost model results for the semi-log functional form

Estimate	Dairy	Hogs	Broilers	Layers
Intercept	-394.26	-317.61	-419.82	-402.05
	(< 0.01)	(< 0.01)	(< 0.01)	(< 0.01)
Corn Grain	55.98	44.94	67.63	48.46
	(< 0.01)	(0.01)	(< 0.01)	(< 0.01)
Soybean Meal	25.83	10.49	57.72	10.73
	(0.026)	(0.58)	(0.014)	(0.55)
DDGS	35.26	48.09	--	26.55
	(0.01)	(0.028)		(0.18)
Meat and Bone Meal	--	--	--	30.86
				(0.057)
Time Trend	2.19	4.77	4.20	3.58
	(< 0.01)	(< 0.01)	(< 0.01)	(< 0.01)
R-Square	0.90	0.88	0.80	0.87

Note: The model is estimated using Seemingly Unrelated Regression (SUR) where dependent variables are feed costs by livestock sector and ingredient prices on the right-hand-side are in logarithmic form, with the exception of the trend term. All prices and costs are in dollars per ton. The numbers in parentheses are p values from two-sided tests of statistical significance of the coefficient estimates. DDGS = corn distiller dried grains with solubles.

Table 3. Marginal feed cost effects of rising corn prices in the Northeast , by livestock sector and price correlation scenario

	Dairy		Hogs		Broilers		Layers	
Corn Price	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**
Base 2007	0.59	0.36	0.50	0.11	0.67	0.85	0.45	0.26
($4.05/bu.)	(0.56, 0.61)	(0.32, 0.40)	(0.47, 0.53)	(0.04, 0.17)	(0.60, 0.73)	(0.78, 0.92)	(0.42, 0.49)	(0.21, 0.30)
+10%	0.53	0.33	0.45	0.10	0.61	0.78	0.41	0.23
	(0.51, 0.55)	(0.29, 0.36)	(0.43, 0.48)	(0.04, 0.15)	(0.55, 0.66)	(0.72, 0.83)	(0.39, 0.44)	(0.19, 0.27)
+25%	0.47	0.29	0.40	0.09	0.53	0.68	0.36	0.20
	(0.45, 0.48)	(0.26, 0.31)	(0.38, 0.42)	(0.04, 0.13)	(0.49, 0.58)	(0.64, 0.73)	(0.34, 0.48)	(0.18, 0.23)
+50%	0.39	0.24	0.33	0.07	0.44	0.57	0.30	0.17
	(0.38, 0.40)	(0.22, 0.26)	(0.32, 0.34)	(0.04, 0.10)	(0.47, 0.42)	(0.54, 0.60)	(0.29, 0.32)	(0.15, 0.19)

Note: Predictions are based on semi-log model in table 2, marginal effects represent the marginal changes in feed costs ($/ton) at various levels of corn prices. Scenario 1 (S1) uses historical corn price correlations computed from the sample data; i.e., soybean meal (SBM) = 0.50 and corn distillers dried grains with solubles (DDGS) = 0.45. Scenario 2 (S2) uses computed price correlations based on future market price predictions in FAPRI (2007); i.e., SBM = 0.97 and DDGS = -0.82. Base 2007 prices (dollars per ton) from the sample data are: corn $144.6 ($4.05/bu.), SBM $229.0, DDGS $140.0, and meat and bone meal (MBM) $255.0. Numbers in parentheses represent 90% confidence intervals.

Table 4. Predicted percentage feed cost changes of rising corn and soybean meal prices in the Northeast, by livestock sector and price correlation scenario

	Corn Price Percentage Changes											
	Dairy						Hogs					
SBM Price	Scenario 1			Scenario 2			Scenario 1			Scenario 2		
Change	10%	25%	50%	10%	25%	50%	10%	25%	50%	10%	25%	50%
10%	4.67	8.46	13.97	2.81	3.65	3.49	3.98	6.85	11.05	1.93	1.54	-0.51
25%	6.01	9.80	15.31	4.15	4.98	4.83	4.42	7.29	11.49	2.37	1.98	-0.07
50%	7.91	11.71	17.21	6.06	6.89	6.74	5.05	7.91	12.11	3.00	2.60	0.56
	Broilers						Layers					
SBM Price	Scenario 1			Scenario 2			Scenario 1			Scenario 2		
Change	10%	25%	50%	10%	25%	50%	10%	25%	50%	10%	25%	50%
10%	5.01	7.68	11.51				3.73	6.55	10.65	2.49	3.34	3.65
25%	7.29	9.97	13.79				4.22	7.05	11.14	2.98	3.83	4.14
50%	10.55	13.23	17.05				4.93	7.75	11.84	3.69	4.53	4.84

Note: Predictions are based on semi-log model in table 2. Corn and soybean meal (SBM) prices represent changes from 2007 base prices (i.e., $144.60/ton ($4.05/bu.) and $229/ton, respectively). Scenario 1 (S1) uses the historical price correlation between corn and corn distillers dried grains with solubles (DDGS) from the sample data, 0.45. Scenario 2 (S2) uses the computed price correlation based on future market price predictions in FAPRI (2007), -0.82. Other prices held at 2007 prices. Scenario 2 for the broiler equation is not applicable since DDGS prices are not included in the feed cost equation.

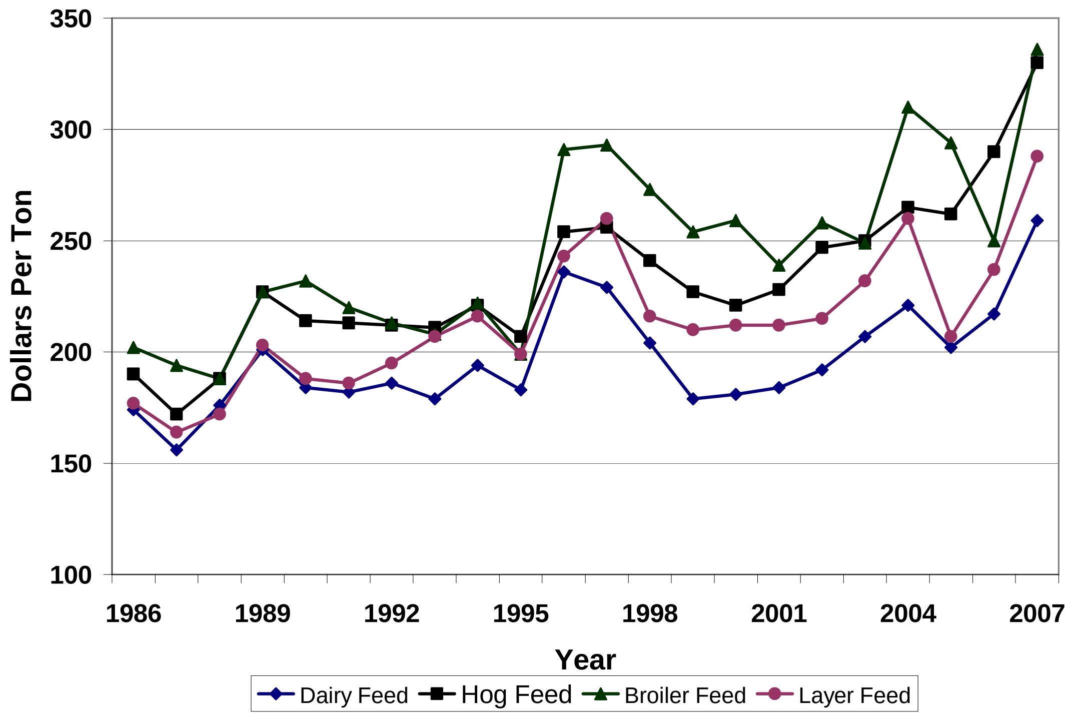

Figure 1. Northeast feed costs by livestock sector, 1986 – 2007