Implications of Growing Biofuel Demands on Northeast Livestock Feed Costs

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The relationship between complete-feed prices and ingredient prices is estimated in order to analyze the effect of higher commodity prices on feed costs, with particular attention paid to the substitutability of corn distillers dried grains with solubles (DDGS). Using the historical price correlation between corn and DDGS, each $1 per ton increase in the price of corn increases feed costs between $0.45 and $0.59 per ton across livestock sectors. Marginal feed costs based on lower forecasted price correlations are reduced between $0.05 to $0.12 per ton across livestock sectors, but only for the dairy ration is the reduction statistically significant. Overall, DDGS cost savings are relatively limited and insufficient to offset the impact of other higher-priced feedstocks.

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

An expanding U.S. biofuels industry and corresponding increased demand for grains and oilseeds is affecting the structure of agricultural commodity markets. While the demand from biofuel processors is well-known, though still a relatively recent factor affecting prices, growing incomes and populations in China and India have also increased the demand for farm commodities. The growing demand, relative to available supplies, has significantly raised the average level of commodity prices. Tighter commodity markets exist, and the result is higher price levels and increased price variability (Westcott 2007).

These price effects have substantial implications for livestock operations, and management adjustments will be required to respond to higher input feed costs. U.S. livestock farmers in the Northeast reported increases in feed costs from April 2006 to April 2007 of 14 percent, 21 percent, 34 percent, and 19 percent, for the hog, layer, broiler, and dairy livestock sectors, respectively (USDA 1986–2008).[1] Record-high commodity prices early in 2008 translated into reported (April) farm feed-cost increases of an additional 14 percent, 15 percent, 50 percent, and 20 percent, respectively, over 2007 levels (USDA 1986–2008).

Given the expectation that corn and soybean meal prices will remain above the levels of the 1990s and early 2000s, there is substantial interest in evaluating the outlook for feed prices and the utilization of biofuel by-product feeds, primarily corn distillers dried grains with solubles (DDGS), as a cost-reducing alternative. While increasing supplies of these by-product feeds may result in lower-priced feed ingredients, several limitations need to be addressed. The ultimate effect on feed costs will vary by livestock sector, given varying feedstock prices and the degree of feasible ration and operational adjustments.

Generally, DDGS feed ingredients can be utilized more readily in ruminant rations than in non-ruminant rations, and the limiting components

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[1] Feed prices are reported regionally by USDA. The Northeast United States comprises the New England states (Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, and Connecticut), New York, Pennsylvania, New Jersey, Delaware, and Maryland.

vary across livestock types. While such feed has been used for years, the recent explosive growth in supplies has led to some problems with inconsistent product quality. The non-standardized nature of the product has resulted in variation in quality within plants across batches and across plants as well (Rausch and Belyea 2005, Chase 2006). This variation comes with a cost in redesigning livestock rations and has been a major limiting factor in increasing utilization in livestock rations.

Nutritional concerns will also limit the amount of the expanded feedstock supply that can be absorbed by the livestock sectors. For example, the relatively high fat and phosphorus levels limits intake in ruminant rations (Chase 2006, Boyles 2007, Stallings 2007), as well as particular concerns over sulfur toxicity, lysine deficiencies, and depressed milk fat levels (Loy 2007, Chase 2006). The fat content is also problematic for hog rations with an industry striving to produce leaner pork products (Whitney et al. 2006). Excessive feeding in poultry rations can lead to lower feed intake and meat yields, and is limited in use by its lower energy and lysine contents, and poor protein quality (Shurson and Noll 2005).

Environmental impacts related to nutrient management can also limit DDGS feeding given increased nitrogen and phosphorus levels in manure (Schmit et al. 2008, Hadrich et al. 2008). For ethanol producers, the value of DDGS co-products is non-trivial, currently equal to roughly one-half of non-corn operating costs (Shapouri and Gallagher 2005). As such, ethanol producers are increasing their attention on product quality and consistency issues, and are considering alternative processing technologies, such as germ and fiber separation equipment, that can address the compositional issues and limiting factors mentioned above (Rajagopalan et al. 2005, Kwiatkowski et al. 2006).

Recent research has used large simulation and/or input-output models to investigate the effects of various biofuel production scenarios on grain and related markets (e.g., Elobeid et al. 2006, English et al. 2007, FAPRI 2005, 2007, Swenson and Eathington 2006). These partial and general equilibrium models integrate related agricultural and other markets to simulate product flows and estimate the quantities and prices reached in equilibrium. Price and quantity effects are reported for the various grain, oilseed, livestock, dairy, and food markets, but the underlying feed-cost impacts and feed-cost relationships are not often reported directly.

Mathematical programming models to determine least-cost rations with respect to commodity prices and nutritional constraints are well understood, dating back to at least the 1950s (e.g., Waugh 1951, Heady and Candler 1958). A vast literature exists that improves on and expands these models to incorporate such things as risk and price dynamics (e.g., Anderson and Trapp 2000, Coffey 2001), or incorporates feed ration choice decisions within a whole-farm model that includes other production decisions and environmental implications (e.g., Schmit and Knoblauch 1995, Teague, Bernardo, and Mapp 1995).

Alternatively, Ferris (2006) utilized an econometric approach to measure the impact and utilization of corn grain and soybean meal in a period of rapidly expanding by-product feed supplies from ethanol production. In his approach, feeds were converted into protein and energy equivalents, and prices for DDGS were generated based on feed composition and computed synthetic energy and protein prices. While Ferris (2006) was able to demonstrate the substitution of ethanol by-product feeds on a nutritional basis, the impacts of this substitution was not related back fully to overall feed costs or differential impacts by livestock sector.

The intent of this paper is to look beyond the determination of a least-cost minimizing feed mix by incorporating additional firm and market factors that affect the underlying technical relationships between input prices and feed costs. From this hedonic-type approach, market data on feed ingredient prices are collected and related to actual reported complete ration feed costs in the northeast United States. This more macro-oriented approach presumes that livestock producers maximize returns and determine the appropriate least-cost rations for their operations incorporating nutritional protocols. However, as mentioned above, ration adjustments and, ultimately, changes in feed costs will depend not only on nutritional feasibility, but also on changes in industry feeding recommendations and technologies over time, whole-farm planning decisions, nutrient management issues, and the availability of a quality, consistent product. Ultimately, the balancing of these supply and demand components should be reflected in feedstock prices and overall feed costs.

Our objective is to examine potential changes in feed costs over a range of anticipated future prices and alternative pricing behaviors of bioenergy by-product feeds. 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. Given an uncertain future, such information can serve as a useful tool for planning production and feeding decisions, as well as for the adoption of strategies and tools to control input costs.

We continue with a discussion of the feed-cost modeling and empirical specifications, followed by a description of the data used. Then, the econometric results and model simulations are discussed. We close with some summary conclusions and directions for future research.

Empirical Framework

The prices of four complete livestock feeds for the Northeast are plotted against years in Figure 1. 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 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 that 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), 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 marginal effects of feed costs may vary with the ingredient 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. 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 we estimate their technical relationships.[2] The availability of ethanol by-products as potential feedstocks, primarily DDGS, is considered in relation to substitutability of other feedstock products, in terms of both energy and protein requirements.

We represent the feed-cost–ingredient price relations using a semi-log functional form. Alternative functional forms (i.e., linear and inverse) were also considered and are discussed below. A general representation of the model can be expressed as

$$
\begin{aligned}
(1)\quad FC_{i,t} &= \beta_0 + \sum_{j=1}^{J} \beta_{i,j} \ln(P_{j,t-\tau}) \\
&\quad + \sum_{j=1}^{J} \sum_{k=2}^{J-1} \alpha_{i,j,k} \ln(P_{j,t-\tau}) \ln(P_{k,t-\tau}) \\
&\quad + \delta_i TR_{t-\tau} + \varepsilon_{i,t} \qquad \forall \quad j \neq k,
\end{aligned}
$$

where $FC_{i,t}$ is the complete feed cost for livestock sector *i* at time period *t*, and $P_{j,t-\tau}$ are lagged (t–τ) feed ration components ($j = 1, \ldots, J$), including primary commodities (corn and soybean meal) and alternative protein and energy processed ingredients (DDGS, meat and bone meal, cottonseed meal, etc.). Lagged ingredient prices are used to account for the time dimension between ingredient procurement and feed manufacturing and use. Given that the ingredient prices are lagged, they are arguably predetermined and thereby preclude concerns about their endogeneity. $TR_{t-\tau}$ represents other lagged input costs in the production of feed such as labor, and is represented as a

[2] While becoming less common, 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" with a 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.

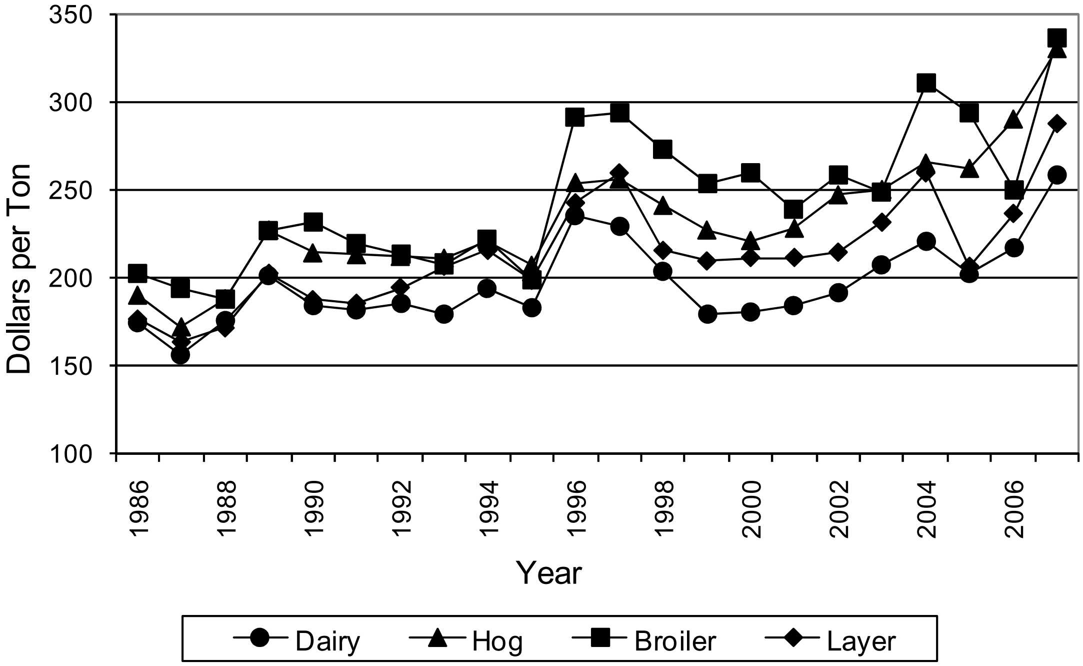

Figure 1. Northeast Feed Costs by Livestock Sector (1986–2007)

Source: USDA (1986–2008).

linear trend variable as an expedient in order to capture the effects that are causing feed prices to adjust, net of ingredient price changes, and the β's, α's, and δ's are parameters to be estimated. Finally, $\varepsilon_{i,t}$ is the error term with mean zero for all sectors i, variance σ_i^2, and covariances across equations of $\sigma_{i,i-}$ for all $i \neq i-$.

A hypothesis is that a curvilinear form is preferable, because as prices increase for one ingredient, feed manufacturers or producers will likely shift to a combination of lower-cost alternatives, but to a decreasing degree as prices rise. Such a model framework allows us to derive technical feed-cost relationships that change continuously with the cost of the respective input. 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 the marginal effects will differ at the data extremes. Ultimately, the alternative forms are evaluated based on their overall statistical fit, within-sample prediction performance, and flexibility in allowing marginal effects on feed prices to vary with the level of ingredient prices.

Data

The data set covers the years 1986 through 2007 (2008 is used later to evaluate ex post feed-cost predictions). All of the costs and prices are in current (nominal) dollars per ton. Defining different price/cost deflators for the left-hand-side (livestock feed) and right-hand-side (feed ingredients) variables is questionable, and using the same deflator on both sides would produce similar statistical results (i.e., scale effects only). Moreover, interest centers on predictions of nominal prices. Annual complete feed costs for the month of April (in dollars per ton) were taken from *Agricultural Prices* (USDA 1986–2008). The costs are based on farm establishment survey responses and represent averages for the Northeast region.

The commodity input and feed ingredient prices were obtained from *Feedstuffs* (1986–2008) and are wholesale prices free-on-board (FOB) at Buffalo, New York. We use a weekly average for the second week in March. Ingredient prices included are based on our judgment and consultation with animal nutritionists about the importance of the particular commodities in feed manufacturing in the Northeast (Table 1).[3]

Input prices were also obtained for additional lagged months, but were not statistically important in preliminary specifications and were not subsequently included. Based on the coefficients of variation (CV), DDGS had the smallest relative variation in prices over the sample period, but all commodities were similar (Table 1).

Model Estimation

The final model estimated across livestock sectors can be expressed as

$$
\begin{aligned}
(2)\quad FC_t^D &= \beta_0^D + \beta_1^D \ln(CP_{t-\tau}) + \beta_2^D \ln(SBMP_{t-\tau}) \\
&\quad + \beta_3^D \ln(DDGSP_{t-\tau}) + \delta_1^D TR_{t-\tau} + \varepsilon_t^D \\
FC_t^H &= \beta_0^H + \beta_1^H \ln(CP_{t-\tau}) + \beta_2^H \ln(SBMP_{t-\tau}) \\
&\quad + \beta_3^H \ln(DDGSP_{t-\tau}) + \delta_1^H TR_{t-\tau} + \varepsilon_t^H \\
FC_t^B &= \beta_0^B + \beta_1^B \ln(CP_{t-\tau}) + \beta_2^B \ln(SBMP_{t-\tau}) \\
&\quad + \delta_1^B TR_{t-\tau} + \varepsilon_t^B \\
FC_t^L &= \beta_0^L + \beta_1^L \ln(CP_{t-\tau}) + \beta_2^L \ln(SBMP_{t-\tau}) \\
&\quad + \beta_3^L \ln(DDGSP_{t-\tau}) + \beta_4^L \ln(MBMP_{t-\tau}) \\
&\quad + \delta_1^L TR_{t-\tau} + \varepsilon_t^L,
\end{aligned}
$$

where the subscripts *D*, *H*, *B*, and *L* refer to the dairy, hog, broiler, and layer sectors, respectively, and where ingredient prices for corn grain, soybean meal, corn distillers dried grains with solubles, and meat and bone meal are represented by *CP*, *SBMP*, *DDGSP*, and *MBMP*, respectively. Interaction effects among feed ingredients were originally included, but were generally insignificant. Hence, we eliminated interaction effects in the final models estimated. The resulting equations are relatively simple, but high collinearity among feed ingredient prices, as well as the relatively small sample size, preclude complex specifications.

Given that the regressors are somewhat different in the four equations, the four equations were estimated as a system of seemingly unrelated regressions (SUR).[4] With the interaction effects removed, the linear functional form does not allow for changes in marginal effects as feed prices change, so it was excluded from further consideration. Also, while both curvilinear forms (i.e., semi-log and inverse) slightly underestimated feed costs at the higher end of corn prices, the semi-log model's marginal effects decline more slowly as prices rise. In addition, within-sample root mean square errors (RMSE) were lower for all equations with the semi-log functional form.[5] As such, the semi-log functional form was preferred and the final equations have good statistical fits, with pseudo R-squared coefficients near or above 0.8 (Table 2).

The trend variable is statistically the most important variable in the equations, and likely captures a collection of important costs such as energy and labor that are moving upward and are highly correlated. This is important in the feed-cost simulations later, and allows us to focus on pricing behavior net of trend effects. Correlation coefficients of the trend term with commodity prices were modest, ranging from -0.39 for DDGS to 0.26 for corn.

DDGS is not included in the final specification for broiler feeds. Original model specifications showed lack of significance and incorrect signs. This type of result is consistent with industry practice where poultry broiler operations use little, if any, DDGS, while its use in layer operations is more common, although still limited. More limited flexibility in using broiler feed ingredients is also evident in the large feed-cost increases over the last two years relative to the other livestock sectors.

The relative size and significance of the various input ingredient parameters will be affected, in part, by the relative contributions of the ingredients to their complete rations. In particular to

[3] Additional feed ingredients (e.g., wheat, wheat middlings, cottonseed meal, canola meal, corn gluten feed, etc.) were considered in preliminary specifications, but exhibited wrong signs and/or were insignificant, largely due to relatively high collinearities with corn grain and soybean meal prices, and were excluded from the final specification.

[4] A SUR chi square test (Judge et al. 1988, p. 456) of whether the error terms across equations were uncorrelated was rejected at the 5 percent significance level for all functional forms; the test statistics for the linear, semi-log, and inverse functional forms were 16.58, 22.12, and 30.39, respectively, with a critical value of 12.59.

[5] Percentage root mean square error (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.

Table 1. Livestock Feed Costs and Ingredient Prices in the Northeast (1986–2007)

Variable	Mean	Std. Dev.	Min.	Max.	CV
	$ per ton				%
LIVESTOCK FEED COSTS					
Dairy feed (18% CP)[a]	196.64	23.92	156.00	259.00	12.17
Hog feed (14%–18% CP)[a]	233.00	35.44	172.00	330.00	15.21
Broiler feed	245.95	40.51	188.00	336.00	16.47
Layer feed	213.59	30.33	164.00	288.00	14.20
FEED INGREDIENT PRICES					
Corn grain (#2, yellow)[b]	100.43	19.09	62.00	147.00	19.02
Soybean meal (49% CP)[a]	206.71	38.90	146.00	301.00	18.82
DDGS[c]	130.68	22.06	88.00	167.00	16.88
Meat and bone meal	218.91	39.76	150.00	300.00	18.16

[a] CP = crude protein
[b] Corresponding corn prices in dollars per bushel are mean 2.81, mininum 1.74, and maximum 4.12.
[c] DDGS = corn distillers dried grains with solubles.

Notes: Feed ingredient prices represent mid-month (for March) wholesale market prices in Buffalo, New York, FOB (*Feedstuffs* 1986–2008). Livestock feed costs represent complete feed costs for April for the Northeast region of the United States (USDA 1986–2008).

Table 2. Livestock Feed Cost Model Results, 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
	(0.03)	(0.58)	(0.01)	(0.55)
DDGS[a]	35.26	48.09	--	26.55
	(0.01)	(0.03)		(0.18)
Meat and bone meal	--	--	--	30.86
				(0.06)
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
DW-test statistic	1.33	1.53	1.85	1.82

[a] DDGS = corn distiller dried grains with solubles.

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.

ruminants, the ratio of corn to soybean meal used will vary depending on the proportions of corn silage (lower) and hay forage (higher) used. Using higher levels of hay forage increases protein contributions to the diet and thereby lowers the requirement for soybean meal. Corn to soybean meal ratios in hog rations are generally similar to those in mixed corn silage and hay forage rations, but finisher rations tend to have a higher corn proportion than those for grower pigs. Poultry rations typically exhibit somewhat lower corn to soybean meal ratios than do rations for hogs, and roasted soybeans are alternatively used.

As expected, the price of corn is statistically the 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 likely due, in part, to the primary ration components described above. However, in all equations except broilers, the estimated marginal price effects for DDGS are greater than those for soybean meal, and likely reflective of the fact that DDGS can substitute some for soybean meal as a protein supplement, as well as for corn grain as an energy (high fat) feed.

The estimated coefficients are, of course, dependent on the sample and, hence, are influenced by the range of input prices and the correlations among prices. The price correlations are reasonably modest, with correlations of corn prices to other prices below 0.50. Soybean meal price correlations with DDGS and meat and bone meal are higher (0.66 and 0.74, respectively), which is expected given increased substitution as protein sources. Variance inflation factors computed for each feed-cost equation are 2.20, 2.20, 1.58, and 2.57 for the dairy, hog, broiler, and layer equations, respectively. Given the model specification, inflation factors below 5.0 suggest that multicollinearity is not a serious issue (Judge et al. 1988, p. 869).

As mentioned above, feed-cost prices in April 2008 were significantly higher than those in April 2007, driven largely by 63 percent and 47 percent increases in soybean meal and corn prices, respectively, over year-earlier levels. In fact, year-over-year comparisons in the data reveal that the 2008 feed-cost increases were nearly as large as those reported in 1996 when corn prices reached an all-time high due to drought-related tighter supplies in the United States and strong demands for corn in China and other parts of Asia. In addition, the 2008 increases were subsequent to already large increases in 2007.

Given the application of our model to prices near or beyond the upper range of prices in the data, we made ex post forecasts of 2008 feed costs. As expected, the forecasts of 2008 feed costs were less than actual feed costs. However, in percentage change terms, predicted levels were relatively close to the actual levels. The broiler equation was an exception, where the model's forecast of an 18 percent rise was unable to replicate the 50 percent reported increase. Otherwise, the predictions of feed-cost increases were 17 percent, 11 percent, and 16 percent over 2007 levels for dairy, hog, and layers, respectively. The actual feed costs for April 2008 were up 20 percent, 14 percent, and 15 percent, respectively (USDA 1986–2008). Combined with the within-sample RMSE statistics, we believe the model is sufficient to evaluate expected changes in feed costs conditional on assumed ingredient prices.

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 under two alternative price intercorrelation scenarios. March 2007 commodity prices for the Northeast are used as the base price levels, and price increases of 10 percent, 25 percent, and 50 percent for corn and soybean meal are evaluated. Nearby futures contract trading in fall 2008 showed corn and soybean meal prices roughly 25 percent to 30 percent above 2007 base-level prices; however, prices in August were roughly 50 percent higher, and the Midwest flooding conditions in June showed prices 80 percent to 90 percent above 2007 base levels. In any event, the range in expected price changes is reasonable.

While DDGS has been used in livestock rations for many years, the supply of DDGS has been small. Thus, historical movements in DDGS prices have closely tracked corn prices. The correlation coefficient between these two price series over the sample period was calculated at 0.45. As expected, corn and soybean meal prices have also been positively correlated, and over our sample period this correlation was 0.50. If corn and DDGS and corn and soybean meal prices continue to be positively correlated as recent history depicts, then increases in corn prices will result in increases in the prices of DDGS and soybean meal.

Whether or not these historical correlations will continue depends on the growth in supplies relative to demand. 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. If DDGS prices do drop, then the price correlation between DDGS and corn could decline and potentially become negative, at least in the short run as the market adjusts to the new volume of DDGS and seeks the long-run price relationship to other feeds. In addition, increasing demand 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 soybean meal prices.

Using FAPRI (2008) national average commodity price forecasts, predicted annual ingredient prices were collected for corn grain, soybean meal, and DDGS for the 2007/2008 through 2017/2018 crop years. Using this data, the expected future price correlation coefficients were computed to be 0.20 between corn and soybean meal and 0.29 between corn and DDGS (FAPRI 2008). The relative softening in both the corn-soybean meal and corn-DDGS price correlations will help ameliorate some of the feed-cost increases expected in the face of increasing ingredient prices, relative to historical standards.[6] We utilize these two sets of price correlations (i.e., the historical estimates and the FAPRI (2008) forecast estimates) to simulate the model over selected price changes to explore the relative impacts on marginal and predicted feed costs.[7]

[6] It is worth noting that these computed correlations are considerably different from year-earlier FAPRI forecasts that showed price correlation coefficients between corn and soybean meal at 0.97 and between corn and DDGS at -0.82 (FAPRI 2007). A closer examination of the USDA (1986–2008) data suggests that the positive correlation between corn and DDGS prices has indeed softened over the last few years, but remains positive. It remains clear that consistently forecasting what these relations will be moving forward is difficult within the current market environment.

[7] For the forthcoming model simulations, we assume the price of DDGS (PD_t) in time period t can be expressed as $PD_t = [1+\rho((PC_t - PC_{t-1})/PC_{t-1})]\times PD_{t-1}$, where PC is the price of corn grain, and ρ is the computed price correlation coefficient. Analogous calculations are made for the soybean meal price and its estimated correlation coefficient with the price of corn.

Marginal (Point) Effects

To begin, we focus on corn prices and estimate the effect on marginal feed costs for the three percentage changes in prices assumed above. The estimated marginal effects, assuming historical positive price correlations, are displayed in Table 3 under the 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 $1 per ton increase in the price of corn [and related (correlated) increases in other feed prices] results in a $0.59 ($0.67) per ton increase in the price of dairy (broiler) feed. This is consistent with the fact that common dairy and broiler feeds use higher relative contributions of corn in their complete feed rations (particularly broilers). The historical positive corn-DDGS price correlation also increases dairy costs. The cost increases are also consistent with the percentage changes in reported feed costs from 2006 to 2007 that showed that feed costs for dairy and broilers increased relatively more than for hogs and layers (USDA 1986–2008). 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, albeit more restrictively as prices continue to increase. In addition, given the price correlation assumptions, increases in corn prices lead to less than proportional increases in soybean meal and DDGS. 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 percent (again assuming that other feed costs rise based on historical correlations to corn prices). Based on computed 90 percent 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 percent for dairy, hogs, and layer rations, and beyond 25 percent for broiler rations.

Marginal feed costs assuming future price correlations based on FAPRI (2008) projections, which include reduced corn-soybean meal and

Table 3. Marginal Feed Cost Effects of Rising Corn Prices in the Northeast, by Livestock Sector and Price Correlation Scenario

	Dairy		Hogs	
Corn Price	------Scenario 1------	------Scenario 2------	------Scenario 1------	------Scenario 2------
Base 2007 ($4.05/bu.)	0.59 (0.55, 0.62)	0.49 (0.45, 0.53)	0.50 (0.45, 0.55)	0.42 (0.37, 0.47)
+10%	0.53 (0.51, 0.56)	0.45 (0.42, 0.48)	0.45 (0.41, 0.49)	0.38 (0.34, 0.43)
+25%	0.47 (0.44, 0.48)	0.40 (0.37, 0.42)	0.40 (0.36, 0.43)	0.34 (0.31, 0.37)
+50%	0.39 (0.38, 0.41)	0.33 (0.31, 0.35)	0.33 (0.31, 0.35)	0.28 (0.26, 0.31)

	Broilers		Layers	
Corn Price	------Scenario 1------	------Scenario 2------	------Scenario 1------	------Scenario 2------
Base 2007 ($4.05/bu.)	0.67 (0.56, 0.77)	0.55 (0.43, 0.66)	0.45 (0.40, 0.50)	0.40 (0.35, 0.45)
+10%	0.61 (0.52, 0.69)	0.50 (0.40, 0.59)	0.41 (0.37, 0.45)	0.37 (0.32, 0.41)
+25%	0.53 (0.47, 0.60)	0.44 (0.37, 0.51)	0.36 (0.33, 0.40)	0.32 (0.29, 0.36)
+50%	0.44 (0.40, 0.49)	0.37 (0.32, 0.42)	0.30 (0.28, 0.32)	0.27 (0.25, 0.29)

Note: Predictions are based on the semi-log model in Table 2. Marginal effects represent the marginal changes in feed costs (dollars per ton) at various levels of corn prices. Scenario 1 uses historical corn price correlations computed from the sample data; i.e., soybean meal = 0.50 and corn distillers dried grains with solubles (DDGS) = 0.45. Scenario 2 uses computed price correlations based on future market price predictions in FAPRI (2008); i.e., soybean meal = 0.20 and DDGS = 0.29. Base 2007 prices (dollars per ton) from the sample data are as follows: corn $144.6 ($4.05/bu), soybean meal $229.0, DDGS $140.0, and meat and bone meal $255.0. Numbers in parentheses represent 90 percent confidence intervals.

corn-DDGS price correlations, are shown under Scenario 2 in Table 3. Marginal feed costs, evaluated at base price levels, are reduced $0.09 (16 percent), $0.08 (15 percent), $0.12 (17 percent), and $0.05 (11 percent) per ton for dairy, hog, broiler, and layer feeds, respectively. While the correlations are still positive, their reduced levels imply relatively smaller increases in DDGS and soybean meal prices when corn prices increase. However, in only the dairy rations are the reductions in marginal feed costs between scenarios statistically different at the 10 percent significance level (Table 3). Recall that both the hog and layer equations have relatively lower estimated feed-cost coefficients for soybean meal and are not statistically different from zero. While the lack of significance is due partially to the relatively modest reductions in price correlations between the two scenarios, the results are consistent with the fact that rations for non-ruminants are generally not able to incorporate as much DDGS as rations for ruminants.

In addition, ration adjustments are arguably more malleable for ruminant rations where changes in forage bases can play a larger role in response to changes in both soybean meal and DDGS price effects. In any event, given the computed 90 percent confidence intervals under Scenario 2, as corn prices increase, the reductions in marginal feed costs from the 2007 base level are significantly different when prices increase 25 percent for dairy rations, but not until there is a 50 percent price increase for hogs, broilers and layers.

Predicted Effects

While the foregoing estimates are useful, particularly in understanding the short-run effect of increased corn prices, the prices of multiple feed-based commodities tend to move together, and it is also useful to isolate changes in DDGS pricing dynamics from changes in feed costs. Hence, we evaluate the impact on feed costs of concurrent increases in corn and soybean meal prices, while still isolating the potential feed-cost savings from the alternative DDGS price relations (Table 4).[8] Under the historical DDGS pricing relationship (Scenario 1), feed costs are expected to increase from 5 percent to 17 percent for dairy and broilers, and from 4 percent to 12 percent for hogs and layers, as corn and soybean meal prices increase from 10 percent to 50 percent.

Scenario 2 shows the estimated feed-cost changes with the reduced corn-DDGS price correlation from 0.54 to 0.29 (Table 4). Given that we are isolating only the impact of the reduced price effects for DDGS, the changes between scenarios are relatively modest. Depending on the pricing scenario, feed costs are reduced 3 percent to 7 percent for dairy, 5 percent to 9 percent for hogs, and 3 percent to 6 percent for layers. When isolating only the corn-DDGS pricing effects, relative cost savings at any given soybean meal price level are modestly higher for hogs than dairy (layers still show the lowest savings potential). Earlier, however, when price effects were adjusted for both DDGS and soybean meal, dairy's marginal feed-cost savings were above those of hogs (Table 3). Intuitively this makes sense due to the additional flexibility in ruminant ration adjustments (e.g., changing forage bases, etc.) in response to meal and grain price changes.

For a given soybean meal price, increases in corn prices increase potential DDGS cost savings; i.e., DDGS can substitute more for corn (for energy) when soybean meal becomes relatively more expensive as a protein source. However, for a given corn price, increases in soybean meal prices reduce the potential DDGS cost savings; i.e., while DDGS can substitute for soybean meal (for protein), DDGS's higher relative fat levels limiting its additive effect as protein becomes the limiting component in rations including DDGS.

Perhaps more generally useful, the results in Table 4 may be viewed as average expected changes in feed costs given either historical (Scenario 1) or expected (Scenario 2) DDGS price correlation assumptions. The fact that using the most recent projections of future pricing behavior results in similar overall cost effects gives some support that history may be as good a guide as any in projecting livestock feeding costs over the long run. Also, 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

High commodity prices fueled by biofuel production growth appear to be a boon to the nation's crop farmers, at least in the short run, but price changes affect the profitability of the nation's livestock production firms through higher feed costs. A statistical model describing the technical relationships between feed ingredient prices and feed costs was estimated for the Northeast for four livestock sectors. This relatively simple macro-oriented approach is particularly useful in that the feed-cost and price data inherently incorporate not only least-cost ration adjustments reflecting nutritional feasibilities, but also changes in industry feeding recommendations and technologies over time, whole-farm planning decisions, nutrient management factors, and the availability of a quality, consistent product.

As expected, changes in corn prices were found to be the primary ingredient driver of feed costs. Evaluated at 2007 prices and assuming historical price correlations between corn and DDGS and corn and soybean meal, each \$1 per ton increase in the price of corn increases feed costs by \$0.59, \$0.50, \$0.67, and \$0.45 per ton 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

[8] Given that the price scenarios reflect changing prices, presumably over a period of time, we also increase the trend variable by one unit.

Table 4. Percentage Feed Cost Changes of Rising Corn and Soybean Meal Prices in the Northeast, by Livestock Sector and Price Correlation Scenario

	Corn Price Percentage Change											
	Dairy						Hogs					
	--------Scenario 1--------			--------Scenario 2--------			--------Scenario 1--------			--------Scenario 2--------		
SBM Price Change	10%	25%	50%	10%	25%	50%	10%	25%	50%	10%	25%	50%
10%	4.7	8.5	14.0	4.5	7.9	13.0	4.0	6.9	11.1	3.7	6.3	10.0
25%	6.0	9.8	15.3	5.8	9.3	14.4	4.4	7.3	11.5	4.2	6.7	10.5
50%	7.9	11.7	17.2	7.7	11.2	16.3	5.1	7.9	12.1	4.8	7.4	11.1
	Broilers						Layers					
	--------Scenario 1--------			--------Scenario 2--------			--------Scenario 1--------			--------Scenario 2--------		
SBM Price Change	10%	25%	50%	10%	25%	50%	10%	25%	50%	10%	25%	50%
10%	5.0	7.7	11.5				3.7	6.6	10.7	3.6	6.2	10.0
25%	7.3	10.0	13.8				4.2	7.1	11.1	4.1	6.7	10.5
50%	10.6	13.2	17.1				4.9	7.8	11.8	4.8	7.4	11.2

Note: Predictions are based on the 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 uses the historical price correlation between corn and corn distillers dried grains with solubles (DDGS) from the sample data, 0.45. Scenario 2 uses the computed price correlation based on future market price predictions in FAPRI (2008), 0.29. 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.

producers will shift to lower-cost alternatives. Using longer-run predictions of commodity price behavior that anticipate reduced price correlations between corn and both soybean meal and DDGS, the estimated increases in feed costs for each $1 per ton increase in the price of corn are reduced to $0.50, $0.42, $0.55, and $0.40, respectively, although only dairy's reduction was statistically different from zero.

In evaluating changes in feed costs across a range of contemporaneous increases in corn and soybean meal prices, initial cost increases were somewhat higher for dairy feeds than for hog and layer feeds. While, generally, DDGS can be substituted in higher proportions in ruminant than in non-ruminant rations, offsetting costs are also affected by the relative proportions of corn and soybean meal in base rations and differences in historical utilization of DDGS across sectors. As price levels increased for corn and soybean meal, however, DDGS cost savings were relatively larger in the dairy rations. In addition, DDGS cost savings increased as corn prices increased, and decreased with increases in soybean meal prices, reflecting, in part, differences in DDGS substitutability in feed rations and the limiting nutritional effects for energy and protein components.

The simulations are point estimates based on the estimated parameters and 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 larger distances from the mean implying larger confidence intervals around the point estimates. Structural changes in feed markets are also occurring given biofuel industry growth. The estimated technical relationships are likely to change over time with a consistent and larger supply of 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.

Notwithstanding these limitations, our results illustrate the consequences for feed costs of higher price levels for corn and soybean meal.

But, these results should not be interpreted as specific forecasts for any particular year, because as just noted, future feed costs will depend on then-existing ingredient price relationships, which themselves must be forecast. As such, improving models that forecast changes in these price relationships over time will continue to be important. In addition, extending the model to other regions would demonstrate possible regional impacts, conditional on spatial differences in ingredient prices and biofuel production.

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