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Implications of Growing Biofuels Demands on Northeast Livestock Feed Costs – Understanding the Technical Relationships Between Ingredient Prices and Feed Costs

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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 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 demands, relative to available supplies, have 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. Northeast U.S. livestock farmers reported increases in feed costs from April 2006 to April 2007 of 14%, 21%, 34%, and 19%, for the hog, layer, broiler, and dairy livestock sectors, respectively (USDA).[1] Record-high commodity prices early in 2008 translated into reported (April) farm feed cost increases of an additional 14%, 15%, 50%, and 20%, respectively, over 2007 levels (USDA).

Given the expectation that corn and soybean meal (SBM) prices will remain high, substantial interest exists in evaluating the outlook for feed prices and the utilization of biofuels 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.

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. Market data on feed ingredient prices are collected and related to actual reported complete ration feed costs in the Northeast U.S. 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, 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. The effects will differ by livestock sector given that DDGS feed ingredients can be utilized more readily in ruminant rations than in non-ruminant rations, and the limiting components (i.e., for energy, protein, fiber, etc.) vary across livestock types. 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

[1] Feed prices are reported regionally by USDA. By definition, the Northeast U.S. includes the New England states, NY, PA, NJ, DE, and MD.

serve as a useful tool for planning production and feeding decisions, as well as the adoption of strategies and tools to control input costs.

Modeling Feed Costs

The prices of four complete livestock feeds for the Northeast U.S. are plotted over time in Figure 1. These prices clearly have trended upward, and the year-to-year changes have some correlation. Presumably, the common 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.

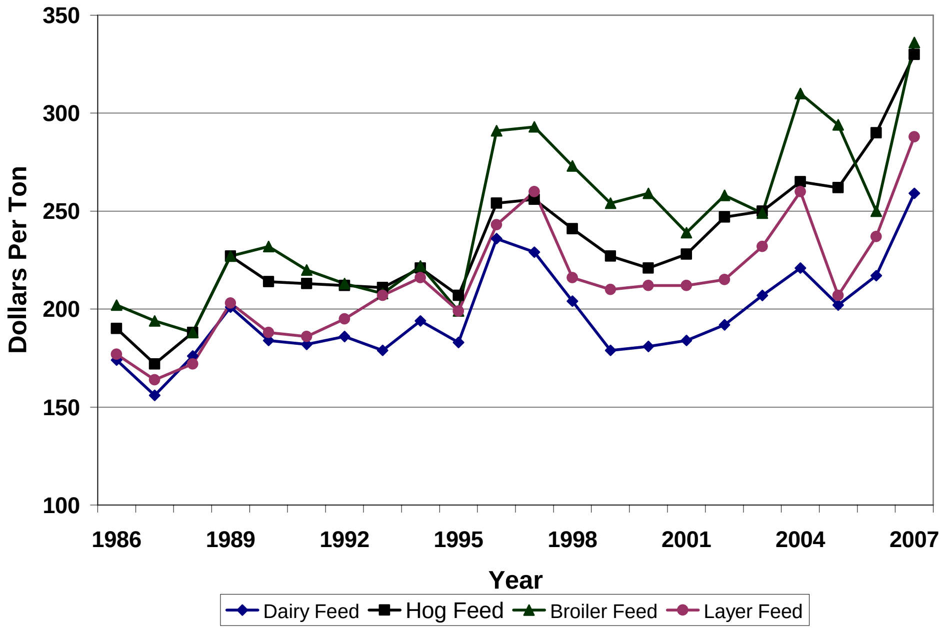

Figure 1. Northeast feed costs by livestock sector, 1986 – 2007

Our analysis of the relationship between ingredient and feed prices is based on a cost framework, where we decompose the price of a feed (say in $/ton) into its primary cost components. Suppose the price of a mixed feed (P_{FEED}) at a particular point in time depends on the prices of two inputs Y and X. Assuming Y and X are used in a 0.6 and 0.4 proportion, then for a point in time, $P_{FEED} = 0.6P_Y + 0.4P_X$, where P_Y and P_X are the individual prices. If we knew all of the possible ingredients in the farmer's decision, as well as inherent profit margin to feed dealer, we could express this equation exactly. However, in practice, the right-hand side is more complex, and the technical coefficients may vary with the price levels. In this context, then, 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 we estimate (see Appendix for details) 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 a residual error term. 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.[2] The availability of DDGS is considered in relation to substitutability of other feedstock products, in terms of both energy and protein needs.

The ingredient prices included in the models (Table 1) are based on our judgment and consultation with animal nutritionists about the importance of the particular commodities in feed manufacturing in the Northeast. Additional feed ingredients were considered in preliminary specifications (e.g., wheat, wheat middlings, cottonseed meal, canola meal, corn gluten feed, etc.), but exhibited wrong signs and/or were insignificant, largely due to relatively high collinearities with the primary ingredients of corn grain and SBM.

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. April complete feed costs were taken from *Agricultural Prices* (USDA). The costs are based on farm establishment survey responses and represent an average for the Northeast region. The commodity input and feed ingredient prices were obtained from *Feedstuffs* and are wholesale prices free-on-board (FOB) Buffalo, NY. We use a weekly average for the second week in March. 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 feed manufacturing in the Northeast (Table 1). Based on the coefficients of variation (CV), DDGS had smallest relative variation in prices over the sample period, but all commodities had similar CVs (Table 1).[3]

DDGS is not included in the final specification for broiler feeds. Original model specifications showed lack of significance and incorrect signs. This type of results 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 ruminants, the ratio of corn to SBM used will vary depending on the proportions of corn silage (lower) and hay forage (higher) fed. Higher levels of hay forages fed increases protein contributions to the diet and thereby lower the requirement for SBM. 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 are alternatively fed.

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[2] While becoming less common in livestock operations, 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, complete feed costs were utilized.

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

Table 1. Northeast U.S. livestock feed costs and ingredient prices, 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	12.17
Hog Feed (14% - 18% CP)	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) [a]	100.43	19.09	62.00	147.00	19.02
Soybean Meal (49% CP)	206.71	38.90	146.00	301.00	18.82
DDGS	130.68	22.06	88.00	167.00	16.88
Meat and Bone Meal	218.91	39.76	150.00	300.00	18.16

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.

The estimated feed cost equations are shown in the appendix (Table A1). The equations have good statistical fits, with the amount of variation in feed costs explained by the feed ingredients and trend terms near or above 80% for all equations. The trend variable is important in the equations, and captures a collection of important costs such as energy and labor that are moving upward and are highly correlated.

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. For all livestock sectors, the estimated marginal price effects (i.e., the increase (decrease) in total feed costs from a one-unit increase (decrease) in the price of the feed ingredient) are greater for DDGS than for SBM, and reflective of the fact that DDGS can substitute some for SBM as a protein supplement, as well as for corn grain as an energy (high fat) feed.

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 price inter-correlations. 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 showed corn prices consistently above $5.00/bushel and SBM prices above $330/ton, approximating a 50% price increase range above 2007 levels, so the range in expected price changes is reasonable.

While DDGS have 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 (implying that roughly a 1% increase in the price of corn was associated with a 0.45% increase in the price of DDGS). As expected, corn and SBM prices have also been positively correlated, and over our 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.

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 relationship between corn and SBM is likely to remain highly, positively correlated. Alternatively, the dramatic growth in ethanol production is resulting in a larger supply 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 it and corn could decline and become negative.

We utilize FAPRI (2007) price forecasts over the next ten years as approximations of expected future market conditions. Predicted annual ingredient prices were collected from FAPRI (2007) for corn grain, SBM, and DDGS for the 2006/2007 through 2016/2017 crop years. The computed price correlation coefficient expected over this time frame between corn and SBM is 0.97, above that exhibited in the historical sample data. The future price correlation between corn and DDGS was computed to be -0.82. A review USDA data suggest that the positive correlation between corn and DDGS prices has indeed softened over the last few years, but remains positive. Since the FAPRI projections anticipate that a negative price relationship will develop over a longer-term horizon, we explore the impacts of these alternative correlation relationships on marginal and predicted feed costs below

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 2 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 higher relative contributions of corn in their complete feed rations (particularly broilers). The positive corn-DDGS price correlation also increases dairy costs.

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 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 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%.

Table 2. Marginal feed cost effects of rising corn prices in the Northeast U.S., by livestock sector & 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: Marginal effects represent the marginal changes in feed costs ($/ton) at various levels of corn prices. Scenario 1 (S1) uses historical price inter-correlations and Scenario 2 (S2) uses estimated future price inter-correlations. Base 2007 prices ($/ton) are corn $145 ($4.05/bu.), SBM $229, DDGS $140, and MBM $255. Numbers in parentheses represent 90% confidence intervals.

Marginal feed costs assuming a negative corn-DDGS price correlation are shown under Scenario 2 (S2) in Table 2. Marginal feed costs, evaluated at base levels, are reduced \$0.19, \$0.23, and \$0.39 per ton for layer, dairy, and hog feeds, respectively. As expected, 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 in this case, are higher for hog and layer feeds (78% and 42%, 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. Recall, however, that nutritional feasibility is but one of several factors that influence the estimated technical coefficients. The estimated technical coefficients also reflect the historical utilization of these ingredients that may be different than that expected with increasing supplies in the future. In any event, given the computed 90% confidence intervals under the S2 scenario, as prices increase, the reductions in marginal feed costs from the 2007 level are not significantly different from zero for hog feeds (i.e., they are statistically unchanged as prices increase), and are only significantly different for the layer equation when prices increase by 50% or more.

The differences in marginal effects across price correlation scenarios, however, are non-trivial. At all price levels and for all livestock sectors, the changes in marginal feed costs, with respect to corn price, are statistically different between the two 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, multiple feed-based commodities are concurrently experiencing significant upside price movements. We evaluate the impact on feed costs of concurrent increases in corn and SBM prices, while still isolating the potential feed cost savings from the alternative DDGS price relations (Table 3). Under the historical DDGS pricing relationship (Scenario 1) feed costs are expected to increase from 5% to 17% for dairy and broilers, and from 4% to 12% for hogs and layers, as corn and SBM prices increase from 10 to 50%.

Scenario 2 shows the estimated feed cost changes when the negative corn-DDGS price correlation exists (Table 3). The estimated effects on feed costs are substantially reduced, ranging from 3% to 7% increases for dairy, 2% to 5% increases for layers, and -0.5% to 3% increases 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 substitute for SBM (for protein), DDGS's higher relative fat levels limits its additive effect as protein becomes the limiting component in DDGS-included rations.

Table 3. Percentage feed cost effects of rising corn and SBM prices in the Northeast U.S., by price correlation scenario

	Corn Price Percentage Change											
	Dairy						**Hogs**					
SBM Price	**Scenario 1**			**Scenario 2**			**Scenario 1**			**Scenario 2**		
Change	**10%**	**25%**	**50%**	**10%**	**25%**	**50%**	**10%**	**25%**	**50%**	**10%**	**25%**	**5**
10%	4.67	8.46	13.97	2.81	3.65	3.49	3.98	6.85	11.05	1.93	1.54	-0
25%	6.01	9.80	15.31	4.15	4.98	4.83	4.42	7.29	11.49	2.37	1.98	-0
50%	7.91	11.71	17.21	6.06	6.89	6.74	5.05	7.91	12.11	3.00	2.60	0
	Broilers						**Layers**					
SBM Price	**Scenario 1**			**Scenario 2**			**Scenario 1**			**Scenario 2**		
Change	**10%**	**25%**	**50%**	**10%**	**25%**	**50%**	**10%**	**25%**	**50%**	**10%**	**25%**	**5**
10%	5.01	7.68	11.51				3.73	6.55	10.65	2.49	3.34	3
25%	7.29	9.97	13.79				4.22	7.05	11.14	2.98	3.83	4
50%	10.55	13.23	17.05				4.93	7.75	11.84	3.69	4.53	4

Note: Corn and SBM prices represent changes from 2007 base prices (i.e., $144.60/ton ($4.05/bu.) and $229/ton, respectively). Scenario 1 (S1) uses histor price inter-correlations, Scenario 2 (S2) uses estimated future price inter-correlations. Scenario 2 for the broiler equation is not applicable since DDGS pric are not included in the feed cost equation.

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), reflecting the additional nutritional substitutability for cattle.

Perhaps more generally useful, the results in Table 3 may be viewed as upper and lower bounds of expected changes in feed costs given either pessimistic (Scenario 1) or optimistic (Scenario 2) DDGS price assumptions. Also, given that the semi-log model underestimated actual feed cost effects at higher ingredient prices, the conditional forecasts at the price extremes

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 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 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 positive price correlation between corn and DDGS continues, each $1/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. Using long-run predictions of a stronger corn-SBM price correlation and a negative corn-DDGS price correlation, the estimated increases in feed costs for each $1/ton increase in the price of corn are reduced to $0.36, $0.11, $0.85, and $0.26, respectively. These results, however, are conditional on a relatively large and negative long-run corn-DDGS price correlation of -0.82. While the existing positive corn-DDGS price correlations have softened recently, these correlations are still above zero.

In evaluating changes in feed costs across a range of contemporaneous increases in 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 in non-ruminant rations, offsetting costs are also affected by the relative proportions of corn and SBM in base rations and differences in historical utilization of DDGS across sectors. As price levels increased for corn and SBM, however, DDGS cost savings were larger in the dairy rations.

Structural changes in feed markets are occurring given biofuels 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 SBM. 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.

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APPENDIX: Regression Model Estimation

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. A representative equation presented in linear form is:

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

where $FC_{i,t}$ is the complete feed cost in region for livestock sector *j* in April of year *t*, $P_{j,t\text{-}\tau}$ are the feed ration components (*j* = 1, …, *J*) including primary commodities (e.g., corn and SBM) as well as alternative protein and energy processed ingredients (e.g., DDGS, meat and bone meal, cottonseed meal, etc.) at year *t*, lagged one or more months (τ) to account for the survey time period and feed manufacturing time from feedstock procurement. $TR_{t\text{-}\tau}$ represents other lagged input costs into the production of feeds such as labor and represented as a linear trend variable as an expedient 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 $\sigma_{i,i\text{-}}$ for all $i \neq i$-.

Three alternative functional forms were considered, including the linear form represented in (1), as well as the semi-log and inverse forms represented in (2) and (3), respectively:

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

$$(3)\ FC_{i,t} = \beta_0 + \sum_{j=1}^{J} \beta_{i,j} P^{-1}_{j,t-\tau} + \sum_{j=1}^{J} \sum_{k=2}^{J-1} \alpha_{i,j,k} P^{-1}_{j,t-\tau} P^{-1}_{k,t-\tau} + \delta_i TR_{t-\tau} + \varepsilon_{i,t} \quad \forall\ j \neq k.$$

The alternative forms were evaluated based on their overall statistical fit and flexibility in allowing 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 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 or producers 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 the marginal effects will differ among functional forms at the data extremes.

The alternative models, following (1), (2), and (3) were initially fitted by Ordinary Least Squares (OLS). 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, precludes complex specifications. That said, the final equations have good statistical fits, with pseudo R-squared coefficients near or above 0.8 (Table A1). Given that the regressors are somewhat different in the four equations, the four equations were also estimated as a system of seemingly unrelated regressions (SUR). A chi-square test supports the use of SUR, but the estimated coefficients are quite similar for the two estimators.

Marginal feed costs are expected to vary as ingredient prices change. 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 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.

Table A1. Livestock feed cost regression 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
	(0.026)	(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
DW-test statistic	1.33	1.53	1.85	1.82

Note: The model is estimated using Seemingly Unrelated Regression (SUR) where dependent variables are feed costs by livestock sector and lagged 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.

OTHER A.E.M. EXTENSION BULLETINS

EB No	Title	Fee (if applicable)	Author(s)
2008-14	Dairy Farm Business Summary, Southeastern New York Region, 2007	($12.00)	Knoblauch, W., Putnam, L., Kiraly, M., Walsh, J., Hulle, L. and C. Wickswat
2008-13	Dairy Farm Business Summary, Western and Central Plateau Region, 2007	($12.00)	Knoblauch, W., Putnam, L., Karszes, J., Grace, J., Munsee, D., Petzen, J. and L. O'Brien
2008-12	Dairy Farm Business Summary, New York Small Herd Farms, 80 Cows or Fewer, 2007	($16.00)	Knoblauch, W., Putnam, L., Kiraly, M. and J. Karszes
2008-11	Cognitive Therapy for Suicidal Patients (3 Video Tapes) **Outside NYS cost is $25.00**		Mastronardi, K.
2008-10	Dairy Farm Business Summary, Northern Hudson Region, 2007	($12.00)	Conneman, G., Putnam, L., Wickswat, C., Buxton, S., Smith, R. and J. Karszes
2008-09	New York FarmNet Stress on the Farm Video (26min)	($20.00)	Mastronardi, K.
2008-08	An Inventory of Educational Resources for Directors of US Agricultural Cooperatives		Henehan, B. and T. Schmit
2008-07	Dairy Farm Business Summary, Western and Central Plain Region, 2007	($12.00)	Knoblauch, W., Putnam, L., Karszes, J., Hanchar, J. and K. Getty
2008-06	Dairy Farm Business Summary, New York Large Herd Farms, 300 Cows or Larger, 2007	($16.00)	Karszes, J., Knoblauch, W. and L. Putnam
2008-05	Cost of Establishment and Production of Vinifera Grapes in the Finger Lakes Region of New York - 2007		White, G.

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