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Value Maximization from Corn Fractionation: Feed, Greenhouse Gas Reductions, and Cointegration of Ethanol and Livestock

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Introduction

Shrinking ethanol margins have heightened the importance of maximizing the value of all outputs from ethanol refinery. To illustrate, on November 28 the cash cost of corn at an Iowa ethanol plant was approximately $3.75 per bushel. This bushel can produce 2.8 gallons of ethanol, which had a market value of approximately $1.80 per gallon, or $5.04 per bushel. With an operating cost of $1.46 per bushel (Lichts, 2006) to convert the corn to ethanol, this leaves a margin over operating costs of only -$0.17 per bushel. However, on November 28, the value for dried distillers' grains with solubles (DDGS), a byproduct of ethanol production, was $0.07 per pound.[2] Processing one bushel of corn produces 17 pounds of DDGS. Therefore, the byproduct value increased the plant's November 28th margin from a meager -$0.17 per bushel to a much more robust $1.028 per bushel (20.2% of ethanol revenue).

Feed byproducts from ethanol will generate even more value if the United States adopts policies that place a value on greenhouse gas reductions. Because distiller's grains are fed to livestock, they displace other sources of feed. Hence, the greenhouse gas emissions associated with producing the displaced feed sources reduce the net greenhouse gas emissions of an ethanol biorefinery. The magnitude of the offset can be large, potentially offsetting a significant proportion of the greenhouse gas emissions of an ethanol plant powered by natural gas.

Currently, most ethanol dry mill plants produce DDGS and then ship them to livestock feeders. Because ethanol is produced primarily in the Corn Belt and most cattle are finished in the Southern Plains, the large increase in DDGS production has meant increased shipping distances. Hogs, which are fed in the Corn Belt, cannot consume all the DDGS that are produced. Because of DDGS fat content and amino acid digestibility concerns, inclusion rates for DDGS are lower for swine than cattle. Increased shipping distance lowers the price of DDGS, as local market value reflects the cost of shipping DDGS to the farthest away market.

Dry mill ethanol plants process the entire corn kernel, even though the starch is the only part of the kernel that produces ethanol; the material left over after distillation is DDGS. An alternative method is to dry fractionate the corn kernel before it enters the mash tank, where the starch is converted to fermentable sugars. Fractionation separates the endosperm (primarily starch), the germ, and the bran. The starch can go into the mash tank, whereas the germ and bran can be processed into different products.

At least two different fractionation methods are being employed. Renessen, a joint venture of Monsanto and Cargill, uses a method that produces corn oil, high protein feed, and a different type of distillers' grain product than currently produced in dry mills. The new Renew Energy plant in Jefferson, Wisconsin, produces a high protein meal, high fat corn germ, and corn bran. The plant is the largest dry mill ethanol plant in operation with capacity to produce 130 million gallons of ethanol per year.

This study has three objectives. Objective one is to estimate the value of ethanol coproducts. This will be achieved by using the shadow values provided when solving a least cost feed ration. The second objective is to determine the potential for enhanced value if the Renew Energy fractionation method is used incorporating greenhouse gas benefits from feed replacement. Finally, the third objective is to determine whether fractionation has the potential to increase the market incorporating additional feeding to swine and poultry.

Research on the economic value of corn ethanol's byproducts is scant. Elobeid *et al.* (2007) estimated that the value of DDGS will move with the price of corn and that domestic and foreign livestock producers will find it profitable to use DDGS in their rations. Shurson (2005) notes that the value of DDGS is often limited by a lack of a consistent standard

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[2] Corn, ethanol and DDG values were taken from USDA-AMS: http://www.ams.usda.gov/mnreports/nw_gr111.txt.

for establishing the nutrient content of DDGS across plants and within plants across time. It is likely that the problem of a lack of a standardized product will only exacerbate with the new products that will come from plants that fractionate their corn.

Ladd and Martin (1976) show how to value byproducts using linear programming to obtain values for input attributes. Melton, Colette, and Willham (1994) extend Ladd and Martin's model to impute the value of input characteristics in inseparable bundles. They estimate the value to a beef producer of genetic characteristics such as birth weight, average gain per day, and slaughter weight, among other things. Yu *et al*. (2002) use a version of these techniques to value different corn quality traits such as increased protein content, increased lysine content, and increased oil content for livestock feed.

In this paper, the value of corn ethanol byproducts is estimated using these standard linear programming techniques for beef cattle and hogs. The value of the byproducts is derived from their ability to substitute for corn and soybean meal in feed rations. For given corn and soybean prices, the imputed value of DDGS and products derived from corn fractionation is estimated to determine the possible increase in feed value from fractionation. DDGS and fractionation products are then allowed to enter least-cost feed rations to determine the amount of corn and soybean meal displacement. This allows the calculation of greenhouse gas credits. Finally, by calculating the change in value of byproducts from fractionation, insight is provided into the extent to which dry mill ethanol plants can be integrated with hog finishing operations.

Valuation of DDGS

Ladd and Martin demonstrated that in a cost minimization problem, the price paid for an input equals the sum of the marginal values of the input's characteristics. This methodology is used to infer the value of traditional distiller's grains and new fractionation products in livestock rations. Although market prices can be observed for DDGS, their reliability in revealing marginal values is questionable because of the rapid supply expansion that has taken place with DDGS. Because fractionation products are so new, there are no observations available on their prices. The maximum willingness to pay for byproducts is estimated by finding the shadow values of energy, protein and lysine, from a corn and soybean meal diet and then apply these values to the energy and protein content of the byproducts. Separate shadow values for beef cattle, dairy cattle, hogs and poultry are found.

The least cost food ration solves:

$$\sum_{i=1}^{6} p_i * X_i \quad \text{subject to} \quad \sum_{i=1}^{6} a_{i,j} X_i \geq b_j$$

Where **x** is a vector of possible feed ingredients (i=1 to 3 for corn and soybean meal and DDGS and/or i=4 to 6 for the fractionated products [corn germ, high protein, and high fiber] depending on the scenario), **p** is the vector of feed prices, **a** is a matrix which translates feed ingredients (i) into values of nutrients (j), and **b** is a vector which represents the minimum requirements of specified nutrients (j) per day. The Lagrangian for this problem is

$$\pounds = px + \lambda[\beta b - ax]$$

where λ is a vector of j Lagrange multipliers. The envelope theorem guarantees that the marginal cost saving at the optimal solution of relaxing the nutrient requirement, b_j , is equal to the Lagrange multiplier λ_j .

$$\partial C\ (x_i^*(p_i, a_i, b_j)) / \partial b_j = \lambda_j$$

Upon solving the producer's cost minimization problem, the value of feed characteristics such as protein and amino acid content is determined. These λ_j, or shadow prices, of the nutrients essentially tell us the value per pound of each nutrient. From the shadow prices for each nutrient present in a feedstuff, the precise value of the feedstuff can be determined for the livestock producer. While this methodology does not provide shadow prices for every nutrient, vitamin, and mineral possible in any feedstock, shadow prices for the most essential nutrients can be recovered using the cost minimization problem.

Determining Shadow Prices

Livestock producers choose from a few main ingredients in formulating their feed rations. Corn, soybean meal, and DDGS are the most popular ingredients (Tiffany and Fruin, 2000). To estimate the shadow values of energy, protein, and lysine to livestock producers requires prices for the main feed ingredients. Because the goal is to estimate the maximum willingness to pay for byproducts, DDGS are not allowed to enter the least cost ration. Rather feed ingredients are limited to corn and soybean meal.[3] Weekly shadow prices for energy and protein for beef cattle, and energy, protein and lysine for hogs from January 2000 to June 2007 are estimated using weekly average nearby CBOT futures contracts for corn and soybean meal for p. For each set of prices in the time series, the producer's cost minimization problem is solved, and the shadow value of each nutrient recorded.

Table 1 shows the nutrient requirements and the feed conversion matrix for finish cattle in a feedlot, A_{cattle}, Jurgens (2002). NE is net energy, NE_m is net energy for maintenance,

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[3] There are a wide variety of feedstocks used to formulate feed rations even without consideration of ethanol byproducts. By limiting feed rations to corn, soybean meal, and synthetic lysine only, we likely overstate the cost of actual least cost feed rations. Hence our measure of the willingness to pay for ethanol byproducts is overstated to the extent that feedstocks other than corn and soybean meal enter the feed ration.

NE_g is net energy for gain, NE_L is net energy for lactation. ME is metabolizable energy. Tables 2, 3 and 4 provide the corresponding information for dairy cattle, hogs and poultry, respectively. Protein and lysine are reported as percent per pound of feed on a dry matter basis. The nutritional requirements have been converted to requirements in pounds per day.

Table 1. Conversion Matrix ($A_{Beefcattle}$) and Requirement Vector[a]

	Corn	Soybean Meal	b
NE[b]	1.38 Mcal/lb	1.44 Mcal/lb	13.43 Mcal/day
Protein	9.1%	43.3%	1.84 lb

[a]Requirements for beef cattle, 1,200 lbs@finish – 660lb/300kg body weight, Table 8-2C (Jurgens, 2002)

[b]$NE = NE_m + NE_g$

Table 2. Conversion Matrix ($A_{Dairycattle}$) and Requirement Vector[a]

	Corn	Soybean Meal	b
NE[b]	1.38 Mcal/lb	1.44 Mcal/lb	28.2 Mcal/day
Protein	9.1%	43.3%	4.96 lb

[a]Requirements for dairy cattle, 660 kg live weight, Table 9-5 (Jurgens, 2002)

[b]$NE = NE_m + NE_L$

Table 3. Conversion Matrix (A_{Swine}) and Requirement Vector b[a]

	Corn	Soybean Meal	b
ME	1.47 Mcal	1.305 Mcal	10.03 Mcal/day
Protein	9.1%	43.3%	0.893 lb
Lysine	0.3%	2.8%	0.0407 lb

[a]Requirements for growing pigs, (80-120kg), Table 7-2B (Jurgens, 2002)

Table 4. Conversion Matrix ($A_{Poultry}$) and Requirement Vector b[a]

	Corn	Soybean Meal	b
NE[b]	1.47 Mcal	1.305 Mcal	2.37 Mcal/day
Protein	9.1%	43.3%	.1841 lb
Lysine	0.3%	2.8%	0.0092 lb

[a]Requirements of 5 week old male broilers, Table 12-4 (Jurgens, 2002)

Valuing DDGS

For each set of weekly corn and soybean meal prices[4], the value of DDGS to dairy cattle, beef cattle, pork and poultry producers is determined from the shadow value of nutrients. The prices represent what a livestock feeder should be willing to pay for corn and soybean meal in North Central Iowa and the price that would be received by the ethanol plant. The following nutrient profile of DDGS is used:[5] 1.67 Mcal/lb in $NE_m + NE_g$ to beef cattle, 1.95 Mcal/lb in $NE_m + NE_L$ to dairy cattle, 1.72 Mcal/lb in ME to swine and poultry, are 30.03% protein, and contain .91% lysine. The resulting imputed values are the maximum prices that livestock feeders would pay for DDGS. If the market price for DDGS were greater than this value then livestock producers would feed corn and soybean meal and would not include DDGS in their feed ration. If the price of DDGS were less than this value, then feeders would feed DDGS. The least cost feed rations were solved with species-specific maximum inclusion rates, which are 40% for beef cattle, 20% for dairy cattle, 20% for hogs and 15% for poultry by weight (Noll, 2005; Schingoethe, Kalscheur, and Garcia, 2002; Shurson and Spiehs, 2002; and Tjardes and Wright, 2002). Figure 1 shows the time series of corn and soybean meal prices.

Figure 2 shows the maximum willingness to pay ($/ton) for DDGS along with actual DDGS prices. As shown, dairy cattle have the greatest willingness to pay for DDGS, closely followed by beef cattle, and then by swine and poultry. All species have a willingness to pay that far exceeds reported plant prices of DDGS.

How are DDGS Priced in the Market?

The discrepancy in Figure 2 between willingness to pay and actual prices received is likely caused by a number of factors including livestock feeders' discounting the value of DDGS because of quality variability, and transportation costs. The corn and soybean meal prices used to calculate the value of DDGS represent the prices paid by livestock feeders in North Central Iowa. DDGS from Iowa are currently being shipped to livestock feeders in many parts of the country, and some are being exported. The spot price of DDGS at an ethanol plant reflects the cost of transportation to the producer who is just at the margin of deciding whether to include DDGS in rations. For example, high transportation costs to a poultry producer in the Southeast may be determining the price received for DDGS. The beneficiaries of pricing DDGS based on the marginal livestock feeder is that cattle producers located near ethanol plants will be able to pay a price that is much below their maximum willingness to pay. A detailed examination of the implications of spatial heterogeneity and transportation costs on the market price of DDGS and on consumer surplus accruing to livestock feeders is beyond the scope of this study.

Abstracting from spatial heterogeneity of livestock operations, consider the market for DDGS where all livestock and ethanol production takes place in the same location, or alternatively, when transportation is costless. Demand for DDGS would come first from the livestock that values it most highly based on its ability to substitute for corn and soybean

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[4] The data are reported by USDA's Agriculture Marketing Service and archived by the Livestock Marketing Information Center.

[5] Nutrient profiles are based on samples taken by Gerald Shurson at the University of Minnesota and reported in various publication and presentations taken from http://www.ddgs.umn.edu/.

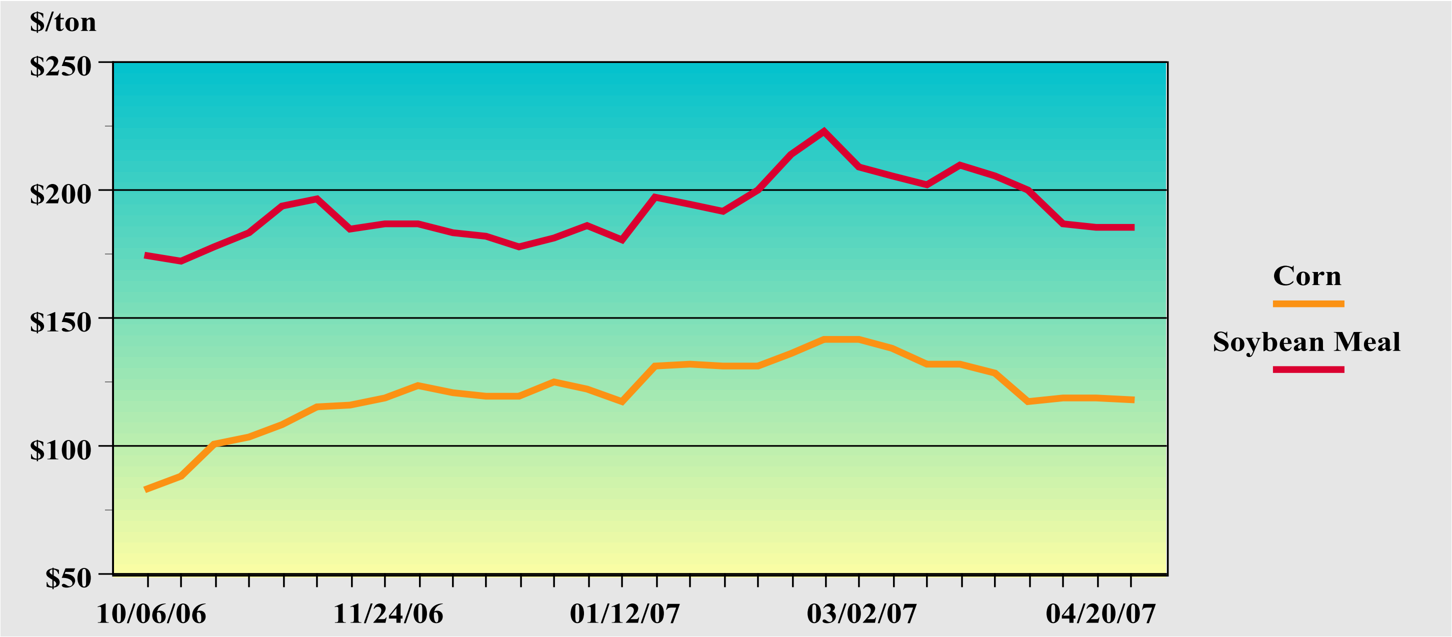

Figure 1. Corn and Soybean Meal Prices
Source: USDA-AMS corn prices for Iowa and soybean meal from the Chicago Board of Trade.

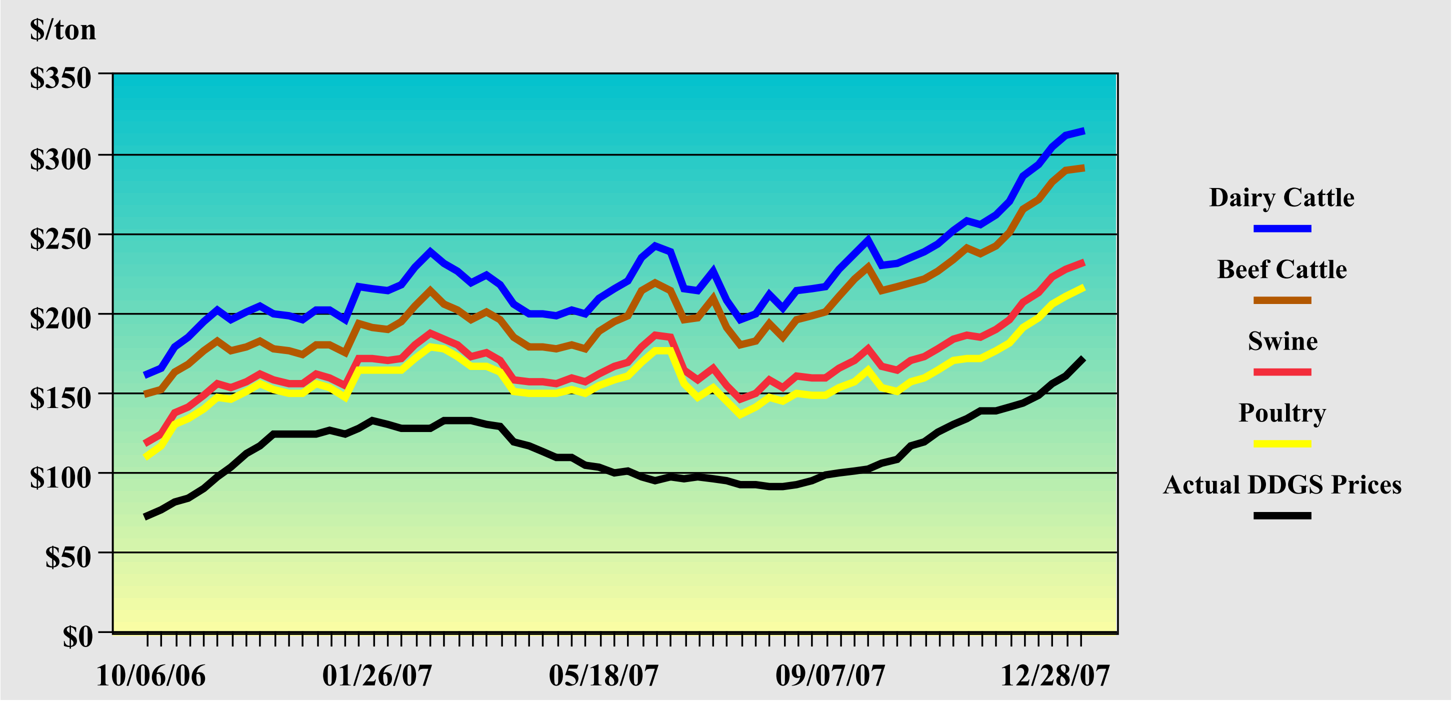

Figure 2. Imputed DDGS Values to Livestock

meal in the feed ration, namely dairy cattle. DDGS will enter the least cost ration as long as the market price is at or below their maximum willingness to pay. If dairy cattle have consumed all they are able to because of maximum inclusion limitations, the animal that values DDGS second most highly, beef cattle, will have to consume DDGS in order for the market to clear. This means the market price for DDGS must be at or below the maximum willingness to pay to beef cattle, dairy producers then enjoy surplus because they will pay a price below their maximum willingness to pay. Knowing the number of animals on feed of each species, and their maximum willingness to pay, the entire demand curve for DDGS can be constructed. The market price for DDGS will have to equal, in equilibrium, the maximum willingness to pay of the marginal species. This assumes that DDGS are of uniform quality and that all livestock producers are able to handle the DDGS in their operation. These assumptions, although somewhat demanding, allows the mechanics of the market to be analyzed. Since DDGS are a byproduct of the ethanol process, their supply is perfectly inelastic with respect to own price, and is fixed by the size of the ethanol industry in this market. When corn is $4.65/bushel and soybean meal is $337/ton the maximum willingness to pay for DDGS of our different livestock types is given in Table 5. From this, the implied demand curve for DDGS can be constructed (Figure 3).

Table 5. Imputed Maximum Willingness to Pay for DDGS ($/ton)

Beef Cattle	Dairy Cattle	Hogs	Poultry
$293.07	$318.16	$236.14	$220.43

Values computed using AMS/USDA Iowa Ethanol Report corn price of $4.65/bu and CBOT soybean meal price of $337/ton on January 14, 2008.

To Fractionate or Not

Ethanol producers have the ability to fractionate corn before creating ethanol, but they will only do so if they can generate more value than the traditional ethanol-DDGS model. The Renew Energy method of fractionation produces three coproducts: a high protein product, a high fat corn germ product, and a high fiber product. To place values on these products, assumptions about the nutrient content of these new byproducts are made. Then the value of these products according to nutrients' shadow values can be determined from the Corn-SBM only ration.[6] The nutrient content for the new coproducts are for every bushel of corn processed, seven pounds of the high protein meal, four pounds of corn germ, and four pounds of bran are produced (Singh, 2006). Table 6 contains the nutrient values.

The imputed per bushel and per ton values for processed corn are presented in Tables 7 and 8 respectively. The per bushel value of the fractionated products is lower for all livestock types. Table 8 shows that the high protein meal has the highest per-ton value followed by corn germ, and then corn bran. Although the high protein meal coproduct has a higher per ton value than DDGS, the weighted average per ton value across all three coproducts is lower than DDGS. These data indicate that at current corn and soybean meal prices there seems to be little incentive for other ethanol plants to adopt the Renew Energy fractionation procedure.[7]

Corn and Soybean Meal Displacement in Livestock Rations and GHG Implications

Ethanol coproducts displace corn and soybean meal that would have been used to feed livestock. Because this displaced feed does not have to be produced, the savings in greenhouse gas emissions from not producing them is counted as a credit towards corn ethanol. The livestock will be fed, and if

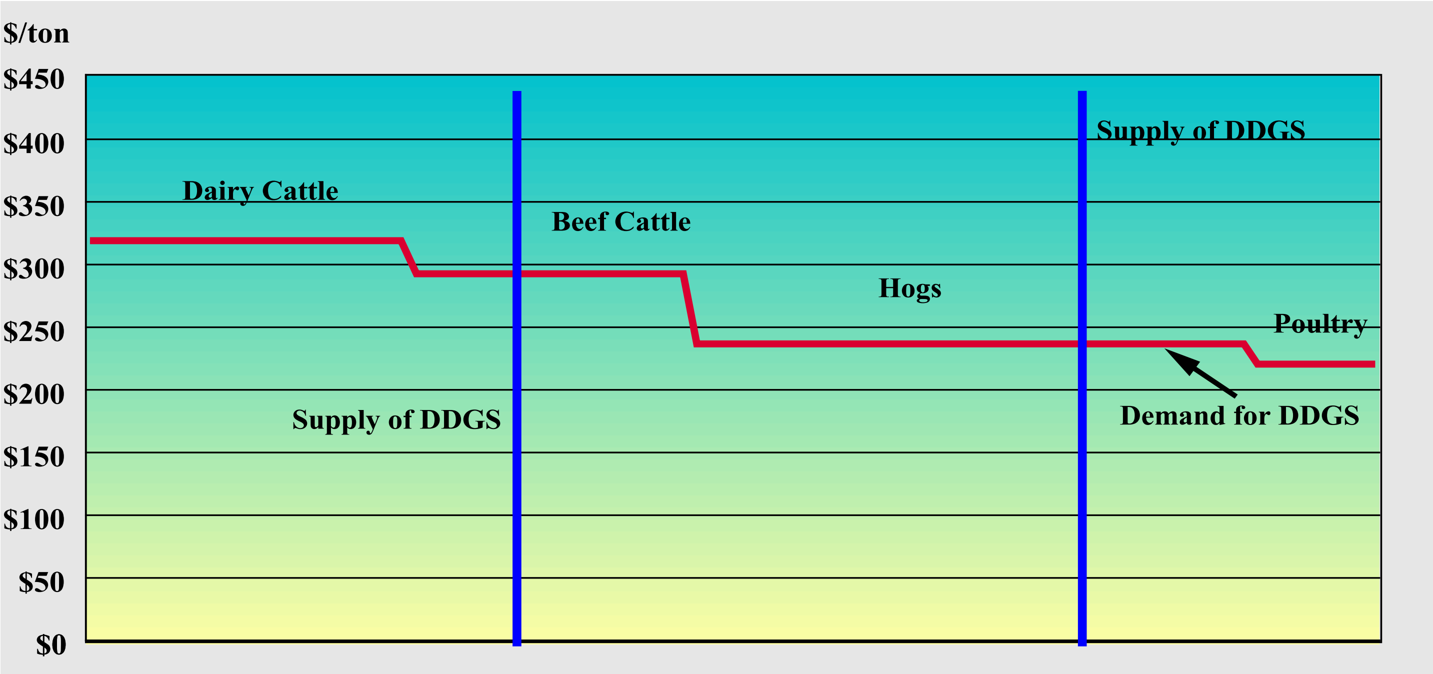

Figure 3. Market for DDGS

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[6] An alternative method is to solve for the implicit value of these new coproducts reflect the value of the new coproducts if they exceed the value of DDGS because the new coproducts would replace DDGS and would be valued on replacing corn and soybean meal in rations.

[7] This conclusion may not hold if other attributes of the Renew Energy coproducts, such as high consistency, are highly valued by feeders. This conclusion also does not imply that other fractionation processes, such as those which result in food grade corn oil, may not generate more value than DDGS.

Table 6. Nutrient Values of New Byproducts from Renew Energy's Jefferson Ethanol Plant

Nutrient	High Protein Meal	High Fat Corn Germ	Corn Bran
NE (Mcal/lb)	1.68	1.73	1.41
ME (Mcal/lb)	1.842	1.727	1.293
Protein	45%	15.06%	5.41%
Lysine	1.27%	0.75%	0.23%

Table 7. Imputed Coproduct Revenue Per Bushel of Corn Processed

Livestock Type	High Protein Meal	High Fat Corn Germ	Corn Bran	Total Revenue per Bushel of Fractionated Products	Total Revenue per Bushel of DDGS
Beef Cattle	$1.28	$0.45	$0.30	$2.04	$2.49
Dairy Cattle	$1.28	$0.45	$0.30	$2.04	$2.70
Hogs	$0/96	$0.45	$0.29	$1.70	$2.01
Poultry	$0.96	$0.45	$0.29	$1.70	$1.87

Values computed using AMS/USDA Iowa Ethanol Report corn price of $4.65/bu and CBOT soybean meal price of $337/ton on January 14,2008.

Table 8. Imputed Coproduct Value ($/ton)

Livestock Type	High Protein Meal	High Fat Corn Germ	Corn Bran	DDGS
Beef Cattle	$366.45	$225.88	$150.85	$293.07
Dairy Cattle	$366.45	$225.88	$150.85	$318.16
Hogs	$388.92	$218.62	$132.11	$236.14
Poultry	$274.99	$224.85	$143.54	$220.43

Values computed using AMS/USDA Iowa Ethanol Report corn price of $4.65/bu and CBOT soybean meal price of $337/ton on January 14,2008.

they are fed corn and soybeans, fertilizer and diesel fuel are used in that process. The GREET model (Wang, 2005) and the EBAMM model (Farrell *et al.*, 2006) provide estimates of the amount of feed displaced. However, their estimates of the amount of feed displaced are much higher than suggested by this study. Hennessy, Rubin and Babcock (2008) calculate that 0.356 pounds of CO_2 equivalent are reduced per pound of corn displaced from feed rations and 0.3321 pounds of CO_2 equivalent are reduced per pound of soybean meal displaced.

Table 9 shows the amount of feed displaced by DDGS and the resulting value per gallon or ethanol at a CO_2 price of $100 per ton, a corn price of $4.65/bu and a soybean meal price of $337/ton. Table 10 does the same for the fractionated coproducts. At a carbon price of $100 per ton, the value of the carbon credit per gallon of ethanol is about 5% of the current price of ethanol and about 20% the market value of distillers grains.

Potential Ethanol-Livestock Integration

Although the per-ton value of DDGS is greater than the per-ton total value of fractionated products, if fractionated products are more suitable for feeding hogs than DDGS, then a greater proportion of the coproducts can be fed to Corn Belt livestock, thereby saving some shipping costs. In addition, because a greater proportion of hogs than cattle are finished in proximity to ethanol plants, fractionated products may lead to greater integration of livestock operations with ethanol plants.

Approximately 53% of U.S. market hogs are raised in Iowa, Minnesota, Illinois, Nebraska, and South Dakota. This represents about 58 million hogs based on total U.S. hog slaughter in 2007. The least-cost amount of DDGS fed per hog per day is 1.38 pounds. This implies that these 58 million hogs could consume all the DDGS produced from 4.82 billion gallons of ethanol. The per-hog daily feeding rate of the three coproducts produced in the fractionation process is 0.186 pounds for high protein meal, 1.047 pounds for corn germ, and 1.28 pounds for bran. At these feeding rates, it would take 19 billion gallons of ethanol to produce bran in surplus of what could be consumed by 58 million hogs, 15.5 billion gallons to produce excess germ, but only 1.6 billion gallons to produce surplus high protein meal.[8] This suggests

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[8] High protein meal is a good substitute of soybean meal. The amount of this coproduct included in hog rations at the imputed price from Table 7 is likely much lower than that which would be included if it were priced at, say the poultry valua-

Table 9. Carbon Credit to Biofuel Plants from Feeding DDGS to Livestock

Livestock Type	Feed Ingredient	Feed Displaced Per Bushel of Corn Processed[a]	Reduction in CO_2 per Gallon of Ethanol Produced	Total Value of Production at a CO_2 Price of $100 Per Ton
		(lb/bu)	(lb/gal)	($/gal)
Beef Cattle	Corn	10.59	1.35	0.12
	Soybean Meal	9.56	1.13	
Dairy Cattle	Corn	14.97	1.90	0.13
	Soybean Meal	8.67	1.03	
Hogs	Corn	16.56	2.11	0.12
	Soybean Meal	3.75	0.44	
Poultry	Corn	17.81	2.26	0.12

Table 10. Carbon Credit to Biofuel Plants from Feeding Fractionated Coproducts to Livestock

Livestock Type	Feed Ingredient	Feed Displaced Per Bushel of Corn Processed[a]	Reduction in CO_2 per Gallon of Ethanol Produced	Total Value of Production at a CO_2 Price of $100 Per Ton
		(lb/bu)	(lb/gal)	($/gal)
Beef Cattle	Corn	11.98	1.52	0.11
	Soybean Meal	5.22	0.62	
Dairy Cattle	Corn	12.54	1.59	0.10
	Soybean Meal	4.69	0.56	
Hogs	Corn	14.32	1.82	0.09
	Soybean Meal	1.27	0.15	
Poultry	Corn	13.79	1.75	0.10
	Soybean Meal	2.93	0.35	

[a] Values computed using AMS/USDA Iowa Ethanol Report corn price of $4.65/bu and CBOT soybean meal price of $337/ton on January 14, 2008. The price of the coproducts was fixed at the levels reported in Table 7 for each species.

that fractionating corn before it is processed into ethanol may reduce the need to transport coproducts a far distance from ethanol plants.

Conclusion

The use and value of coproducts of producing corn ethanol are critical issues facing the industry as it expands to meet the increased ethanol mandates of the Energy Independence and Security Act. Significantly higher corn and soybean meal prices have led the U.S. livestock industry to bid up the price of DDGS grains as a substitute feed ingredient. Higher prices for DDGS have, in turn, helped the ethanol industry offset increased feedstock prices. With ethanol set to expand to meet the new mandates, the cost of shipping DDGS to new feeders (perhaps overseas) will only increase, which will reduce the equilibrium price paid for DDGS. Future values of DDGS may be enhanced if they can offset the greenhouse gas emission of ethanol plants or if they can be reformulated into coproducts that can be fed at higher rates than DDGS.

Fractionation of corn before it is processed into ethanol can create new coproducts that have the potential of increasing value to ethanol producers. The maximum willingness to pay for DDGS and new coproducts that are created by the fractionation process adopted by Renew Energy at its plant in Jefferson, Wisconsin, are calculated by determining the amount of corn and soybean meal displaced after DDGS and the new coproducts are allowed to enter least cost feed rations. Contrary to expectations, the maximum willingness to pay per ton of DDGS by livestock feeders that are near Iowa ethanol plants is greater than the value of coproducts calculated by taking the weighted average of the maximum willingness to pay for each coproducts, weighted by the share of coproducts produced per bushel of corn processed. Only one of the coproducts—high protein meal—has an imputed per ton value that is greater than DDGS. This lower value suggests that ethanol plants may be slow to adopt fractionation processes for their plants.

Two of the new coproducts can be fed to hogs at much higher rates than DDGS. This implies lower shipping costs because they can be fed to the animal species most in abundance where ethanol is produced. This savings of shipping

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tion or if the feed had to be transported a far distance.

costs will increase their value, suggesting that they will have an equilibrium market price closer to the calculated maximum willingness to pay than for DDGS.

Because feeding coproducts displaces corn and soybean meal in rations, the greenhouse gas emissions associated with the feeding of corn and soybean meal can help offset the ethanol plant emissions. How least-cost feed rations change after allowing coproducts to enter rations is a natural way to estimate feed displacement. The results of this study indicate that feed displacement rates commonly used in the literature are too high. At a CO_2 price of $100 per ton, the value of greenhouse gas credits from coproducts is about 5% of the value of ethanol or 20% of the value of DDGS, which suggests that high-priced CO_2 can create a significant new revenue stream.

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