The Long-Run Impact of Corn-Based Ethanol on the Grain, Oilseed, and Livestock Sectors: A Preliminary Assessment

Amani Elobeid, Simla Tokgoz, Dermot J. Hayes,
Bruce A. Babcock, and Chad E. Hart

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Center for Agricultural and Rural Development
Iowa State University
Ames, Iowa 50011-1070
www.card.iastate.edu

Amani Elobeid and Simla Tokgoz are international sugar and ethanol analyst and international grain and ethanol analyst, respectively, in the Center for Agricultural and Rural Development (CARD), Iowa State University. Dermot Hayes is professor of economics and of finance, and Pioneer Hi-Bred International Chair in Agribusiness, Iowa State University. Bruce Babcock is professor of economics and director of CARD. Chad Hart is head of the Biorenewables Policy Division in CARD.

Questions or comments about the contents of this paper should be directed to Bruce Babcock, 578 Heady Hall, Iowa State University, Ames, Iowa 50011-1070; Ph: (515) 294-6785; Fax: (515) 294-6336; E-mail: babcock@iastate.edu.

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Executive Summary

The ongoing growth of corn-based ethanol production raises some fundamental questions about what impact continued growth will have on U.S. and world agriculture. Estimates of the long-run potential for ethanol production can be made by calculating the corn price at which the incentive to expand ethanol production disappears. Under current ethanol tax policy, if the prices of crude oil, natural gas, and distillers grains stay at current levels, then the break-even corn price is $4.05 per bushel. A multi-commodity, multi-country system of integrated commodity models is used to estimate the impacts if we ever get to $4.05 corn. At this price, corn-based ethanol production would reach 31.5 billion gallons per year, or about 20% of projected U.S. fuel consumption in 2015. Supporting this level of production would require 95.6 million acres of corn to be planted. Total corn production would be approximately 15.6 billion bushels, compared to 11.0 billion bushels today. Most of the additional corn acres come from reduced soybean acreage. Wheat markets would adjust to fulfill increased demand for feed wheat. Corn exports and production of pork and poultry would all be reduced in response to higher corn prices and increased utilization of corn by ethanol plants. These results should not be viewed as a prediction of what will eventually materialize. Rather, they indicate a logical end point to the current incentives to invest in corn-based ethanol plants.

Keywords: biofuels, commodity markets, corn price, energy markets, ethanol.

THE LONG-RUN IMPACT OF CORN-BASED ETHANOL ON THE GRAIN, OILSEED, AND LIVESTOCK SECTORS: A PRELIMINARY ASSESSMENT

Introduction

The recent growth in U.S. ethanol production has been impressive, and there is every indication that this growth will continue. Because commercially viable ethanol facilities require large amounts of corn, the rapid growth in the number of these facilities will have a significant impact on U.S. and world agriculture. To date, there have been limited attempts to use economic tools and models to examine the likely size of the ethanol industry or the impact of this industry on the rest of U.S. and world agriculture.[1]

This analysis makes two contributions. First, we examine the profitability of ethanol production and the incentives for investors to fund these facilities. This examination allows us to calculate the corn price that will cause this expansion to stop. Second, we use a broad model of the world agricultural economy to evaluate the likely impact of U.S. ethanol production on agricultural markets.

Methodology

Available estimates of total potential energy production from U.S. and international agriculture are typically based on trend-line projections, which in turn are based on ongoing and planned facilities.[2] Most of the work that we are aware of is based on a numeration of current and planned facilities and not on the economic forces that will bring this expansion to a halt. We address the question of how much ethanol will be produced using a different approach. As long as there are profits to be made, investment in ethanol plants will continue. Eventually profits will fall to zero because either the price of ethanol will fall or the price of feedstock will increase. If the determinants of ethanol profitability can be modeled, then we can use the model to estimate the long-run supply curve of ethanol.

The preliminary work presented here is based on the following logic. For any crude oil price we can calculate the expected market value for unleaded gasoline. We can then find the market price that makes flex-fuel vehicle owners indifferent between using E-85 and unleaded gasoline. This long-run ethanol price allows us to calculate the corn price that facilities can pay while still covering all costs. We assume that investors in ethanol plants will continue to invest until corn prices reach this critical level. Once we know this long-run equilibrium corn price, we can calculate how much corn-based ethanol production it will take to cause corn prices to increase to this (break-even) level.

We first exogenously increase ethanol demand, which induces a higher demand for corn used in ethanol production. This additional corn demand is then introduced into a large-scale model of U.S. and world agriculture until the model suggests a corn price at the critical level. One advantage of the use of this model is that we are also able to evaluate the adjustments in U.S. and world agriculture in response to this new demand for corn.

There are limited numbers of sets of commodity models that have the required multi-commodity international coverage and the cross-commodity inter-linkages to allow all of the various interactions that are needed for this study. One set of these models is developed and operated by analysts at the Food and Agricultural Policy Research Institute (FAPRI) at Iowa State University and the University of Missouri. We employ modified versions of these models to examine how world agriculture will respond to the set of prices that will cause the agricultural energy sector to stabilize.[3]

Alternative Scenarios

As with all forward-looking analysis, we understand that changes in world events that occur after our work has been completed may limit the accuracy and applicability of this work. Therefore, we have also conducted an analysis of how changes on all of our key parameters (prices of energy and dried distillers grains with solubles; biofuels production; release of Conservation Reserve Program acres,[4] corn and oilseed yields; and public policy) would alter our results and conclusions.

Assumptions

Energy Prices

The critical assumption is that crude oil prices remain at $60 per barrel. At the time of writing, this assumption seems conservative because the NYMEX light crude oil futures market is trading at a range of $60 to $65 per barrel for delivery in the period 2007 to 2012. Using the historic relationship between crude oil and unleaded gasoline, this $60 crude oil price translates into a wholesale gasoline price of $2.07 per gallon. We assume that ethanol production will eventually become so large that the price of ethanol will be driven only by its energy value. Again to be conservative, we assume that ethanol's energy value is 0.667 that of gasoline. This implies that the energy-equivalent price of ethanol, given a $2.07 per gallon price for gasoline, is $1.38 per gallon. When the volumetric ethanol excise tax credit (VEETC), a tax credit offered to refiners for blending ethanol with gasoline, of $0.51 per gallon is added to this price, the ethanol price increases to $1.89 per gallon. The full amount of the tax credit will be reflected in the corn price assuming competition between blenders is sufficiently high.

Of course, to utilize large amounts of ethanol, the United States will need extensive expansion in the number of flex-fuel vehicles in use. Because this is a long-run analysis, we implicitly assume that the number of flex-fuel vehicles is not a limiting factor.

Operating Costs and Performance

Because we are looking at a marginal ethanol plant to be built (or not built) at some date in the future, we assume that the facility is a 50-million-gallon ethanol plant. This plant has an ethanol yield of 3 gallons per bushel and a DDGS (dried distillers grains with solubles) yield of 17 pounds per bushel. We further assume that the price of DDGS remains at the current level of $77.56/ton, providing a credit of $0.66 per bushel of corn used by the plant. We assume that operating costs for an ethanol plant are $0.52 per gallon or $1.56 per bushel (F.O. Lichts, 2006). The proposed plant costs $80 million, which when amortized over 10 years indicates a capital cost of $0.24 per gallon, or $0.72 per bushel.

Calculating the Long-Run Equilibrium Corn Price

The ethanol plant earns $5.67 for the ethanol produced from one bushel of corn; it also receives $0.66 per bushel for the DDGS co-product. The total cost of processing this bushel is $2.28 ($1.56 for variable costs and $0.72 for fixed costs). We can subtract total costs per bushel from total revenue per bushel to arrive at the break-even price for corn. This equals $6.33 minus $2.28 or $4.05. This means that the plant can pay as much as $4.05 for corn and continue to service all of its fixed and variable costs. We assume that investors in this plant are aware of this calculation and that they will continue to invest as long as they expect the average price of corn delivered to the plant to cost less that this critical amount.

We realize that in the real world there will be tremendous uncertainty about local corn prices at the time ethanol plants are being built. This suggests that investors will probably be cautious about constructing the last few plants. However, one could also argue that too many plants will be built because the market will overshoot the long-run equilibrium value. In addition, we are ignoring a federal income tax credit of $0.10 per gallon ($0.30 per bushel) on plants with a capacity below 60 million gallons. If our price assumptions are correct, ethanol production will stop growing when corn prices are approximately $4.05. We provide these equilibrium corn prices for a wide variety of crude oil prices in Table 1.

To see why this method does not produce a forecast of the future price of corn, consider the following analogy. Assume that pork prices are at $60 per hundred pounds and that production costs are $40 per hundred pounds. Most agricultural economists would predict an expansion in pork production and would calculate the amount of additional pork required to bring the price of pork back to the production cost. In reality, it is likely that high profits in pork production will cause expansion, but it is unlikely that this expansion will stop at just the right time to bring pork prices back to exactly the level of production costs. Note also that there is no real time line with our approach; we are simply interested in the long-run equilibrium price and not in the path that gets us there.

All of the results presented next are based on the analysis just described. This means that they should not be interpreted as predictions or associated with any particular time path.

TABLE 1. Long-run equilibrium corn prices at various crude oil prices

With the VEETC			
Crude Oil Price *($/barrel)*	**Gasoline Price** *($/gallon)*	**Ethanol Price** *($/gallon)*	**Corn Price** *($/bushel)*
40	1.38	1.43	2.67
50	1.73	1.66	3.36
60	2.07	1.89	4.05
70	2.42	2.12	4.74
80	2.76	2.35	5.43
Without the VEETC			
Crude Oil Price *($/barrel)*	**Gasoline Price** *($/gallon)*	**Ethanol Price** *($/gallon)*	**Corn Price** *($/bushel)*
40	1.38	0.92	1.14
50	1.73	1.15	1.83
60	2.07	1.38	2.52
70	2.42	1.61	3.21
80	2.76	1.84	3.90

How Big Will the Ethanol Industry Get?

Our analysis suggests that the U.S. corn-based ethanol industry will continue to expand until the market price of corn reaches $4.05, and after all related markets are in equilibrium. Our next task is to determine how much ethanol production it will take to drive corn prices up to that amount. To accomplish this we added an exogenous demand shock to the existing multi-commodity, multi-country modeling system until the projected market price for corn equaled $4.05. The system allows for interactions across a wide range of commodities and countries. This means that the adjustments required to free corn for the U.S. ethanol industry are felt all over the world. For example, Argentinean corn producers adjust by growing more corn, whereas U.S. and Chinese consumers respond by buying less pork. By allowing so many markets to adjust, the model predicts that an enormous amount of corn will become available, as shown in Table 2.

Table 2 shows U.S. corn area increasing by 21% and U.S. ethanol production increasing so that corn use in ethanol production exceeds 11 billion bushels. These adjustments allow the U.S. ethanol industry to expand to 31.5 billion gallons. At this level of

TABLE 2. Long-run equilibrium in U.S. corn and ethanol markets

	CARD International Ethanol Baseline (2015)[a]	Estimated Long-Run Solution	Percentage Change
Corn Price (*$/bushel*)	2.56	4.05	58%
Corn Area (*million acres*)	79.4	95.6	21%
Corn Production (*million bushels*)	13,040	15,656	20%
Corn Use in Ethanol (*million bushels*)	3,251	11,103	242%
Ethanol Consumption (*million gallons*)	9,476	31,479	232%

[a]For more details on the baseline numbers, see Elobeid and Tokgoz, "Removal of U.S. Ethanol Domestic and Trade Distortions: Impact on U.S. and Brazilian Ethanol Markets," CARD Working Paper 06-WP 427, October 2006.

production, the corn-based ethanol industry will provide approximately 20% of the fuel needs for the domestic transportation system projected for 2015. This is not a projection of ethanol production in 2015; the year 2015 is used to show the relative size of the industry given the estimated long-run solution. This amount of ethanol production far exceeds the capacity of the existing industry as well as forecasts based purely on the number of plants under construction. The only comparable production values are from William Tierney, who tracks ethanol plants that are planned and those that are under construction (Tierney 2006). His estimates indicate that if all the plants that are planned are built, then total ethanol production will reach 26 billion bushels by August 2009. Our analysis suggests that if oil prices remain at $60 or more, then most of these planned plants will actually be built. It also suggests that as many as 5 billion gallons of new capacity will be announced and will come online after August 2009.

Impact on Soybean Markets

Although all sectors of world agriculture are expected to adjust as the U.S. ethanol industry expands, the sector most influenced by this expansion is the U.S. soybean sector. High corn prices will provide an incentive to plant more corn acres and an expansion of DDGS production will create competition for soybean meal. The results presented in Table 3 show a slightly lower soybean price with higher soybean oil prices being offset by lower soybean meal prices and a 9-million-acre reduction in soybean area. This

TABLE 3. Long-run impact on the U.S. soybean industry

	CARD International Ethanol Baseline (2015)	Estimated Long-Run Solution	Percentage Change
Soybean Price (*$/bushel*)	5.52	5.22	-5%
Soybean Area (*million acres*)	68.6	59.3	-14%
Soybean Production (*million bushels*)	3,014	2,599	-14%
Soybean Domestic Use (*million bushels*)	2,117	1,850	-13%
Soybean Meal Price (*$/ton*)	160.2	92.7	-42%
Soybean Meal Use (*thousand tons*)	37,634	15,179	-60%
Soybean Oil Price (*$/cwt*)	27.2	32.5	20%

adjustment can be achieved if approximately half of corn-soybean producers switch from a corn-soybean rotation to a corn-corn-soybean rotation.

These results ignore the positive impact of biodiesel on soybean oil prices and therefore likely overestimate the impact on this sector. The trade-off between corn acres and soybean acres is probably the most suspect part of our analysis. The models we use are based on past behavior, and the predicted relative prices of corn and soybeans are outside of the range of this behavior. It is possible that more soybean acres will come out of production than we indicate here. However it is also possible that biodiesel expansion will allow the soybean industry to limit the soybean area that will switch to corn. If this occurs, then corn prices will rise much quicker, leading to smaller corn-ethanol production than calculated here.

Impact on Wheat Markets

The impact on U.S. wheat markets is presented in Table 4. The table shows a 20% increase in wheat price and a 3% reduction in wheat area. In terms of wheat domestic use, the significant impact is felt in the feed sector, with feed use increasing from 150 million bushels to 283 million bushels. This higher demand occurs despite the higher wheat price, as less corn is available for feed use and the corn price increase is larger relative to the increase in the wheat price. With higher domestic use, lower production, and higher wheat prices, wheat exports decline by 16%.

TABLE 4. Long-run impact on the U.S. wheat industry

	CARD International Ethanol Baseline (2015)	Estimated Long-Run Solution	Percentage Change
Wheat Price (*$/bushel*)	3.80	4.60	20%
Wheat Area (*million acres*)	47.7	46.3	-3%
Wheat Production (*million bushels*)	2,120	2,052	-3%
Wheat Food Use (*million bushels*)	935	922	-1%
Wheat Feed Use (*million bushels*)	150	283	88%
Wheat Exports (*million bushels*)	1,043	875	-16%

Impact on Other Sectors

The U.S. ethanol industry is protected from competition by a 2.5% ad valorem tariff and a specific duty of $0.54 per gallon ($1.62 per bushel equivalent) on imported ethanol.[5] This tariff coupled with the ethanol production incentive described earlier helps isolate the U.S. ethanol industry from the rest of the world. Together these interventions will cause the U.S. corn-based ethanol industry to grow at a faster rate than would otherwise have been the case. The increased demand for corn will crowd out U.S. corn exports and allow South American corn producers to move into markets that are currently supplied by U.S. corn exports. The model suggests that once the size of the U.S. ethanol industry reaches about 22 billion gallons, the U.S. will no longer have a surplus of corn to export. This does not mean that current corn-importing countries will face a scarcity of corn. It does, however, mean that they will source their corn from countries such as Argentina, which has the capacity to produce large amounts of additional corn.

The results indicate that corn used for feed by U.S. livestock falls by 33%, from 6,032 billion bushels in the baseline to 4,032 billion bushels in the scenario. Some of this adjustment is made possible by an increased use of DDGS, especially in the beef and dairy sectors, and increased use of wheat, hay, and pasture. However part of the reduction will be achieved by reductions in the size of the U.S. pork and poultry industries.

As long as the U.S. is exporting some corn, U.S. prices will equal the world corn price minus transportations costs. This means that as U.S. corn prices rise, world corn prices will also increase. U.S. livestock producers will experience higher feed costs and this will cause some to exit the industry. This reduced production will cause an increase in market prices, and domestic and international consumers will pay higher prices for U.S. livestock products. The impact on pork and poultry producers will be most severe because these sectors are least able to switch from corn-based diets to DDGS-based diets.[6]

Professor John Lawrence of Iowa State maintains a set of estimated returns for typical Iowa pork producers. His current budgets show a $1.85 per bushel corn cost and a total production cost per head of $101.50. If we increase the corn price from $1.85 to $4.05 this increases corn costs per animal from $27 to $58 and increases total production costs by approximately 31%. U.S. pork production will need to decline by 10% to 15% to allow the industry to pass this cost increase on to the wholesale market.

If the U.S. becomes a corn importer (as the model suggests), then the U.S. pork and poultry sectors will lose their international competitiveness, and exports of these products will fall rapidly, further reducing the size of these sectors. We are unable to apportion further the breakdown by livestock species at this point because we are in the process of upgrading the model system to better incorporate DDGS. We will be able to add additional species-specific information in our next report.

Sensitivity Analysis

The results in Table 5 show the impact of some key assumptions. The results are most sensitive to the price of crude oil and to the tax credit that is provided to ethanol blenders. The results are not particularly sensitive to the import tariff alone, the release of Conservation Reserve Program acres, or to the prices of DDGS and natural gas.

Qualifications

We have not examined the impact of weather uncertainty. Were we to introduce the possibility of a drought scenario, then the impacts would be greater than those shown here.

TABLE 5. Impact of Various Scenarios on U.S. Ethanol Production and Corn Feed Use

			Percentage Change from Long-Run Solution with $60 crude oil	
Scenario	**Ethanol Production**	**Corn Feed Use**	**Ethanol Production**	**Corn Feed Use**
	(*million gallons*)	(*million bushels*)		
$70 crude oil; $4.74 corn price	43,679	3002	40%	-26%
$50 crude oil; $3.36 corn price	19,091	5,009	-39%	24%
No tariff and tax credit; $2.52 corn price	7,148	6,127	-77%	52%
No tariff	30,606	4,047	-2%	0%
Addition of 3 million acres of CRP to corn area	31,220	4,131	0%	2%
DDGS price increases by $10; $4.14 corn price	32,511	3,906	4%	-3%
DDGS price decreases by $10; $3.90 corn price	29,824	4,150	-4%	3%
No corn imports	30,898	3,759	-1%	-7%
20% increase in natural gas price; $3.90 corn price	29,810	4,152	-4%	3%
20% decrease in natural gas price; $4.20 corn price	32,944	3,875	6%	-4%

[a] All corn prices listed in this table are the energy-equivalent break-even corn prices, given crude oil prices.

We have also ignored the possibility that high corn prices will stimulate additional research to increase corn yields. The model assumes that trend yields continue to grow at the same rate as in recent years. If it is possible for the seed sector to create and introduce additional varieties before the critical corn price is reached, then the likely size of the ethanol industry will be larger than that shown here and the impacts on other sectors will be less severe. We also have not accounted for the possible development of ethanol production from other cellulosic materials. If and when ethanol production from other cellulosic sources develops, it will affect the size of the impacts outlined in this report.

Who Wins and Who Loses?

Much of the debate surrounding the current incentives to the ethanol sector suggests that these incentives are driven in large part by a desire to reduce U.S. dependence on imported oil. By stimulating the production of ethanol to as much as 20% of total fuel use, these incentive structures appear to be well on their way to meeting this goal.

Other beneficiaries include landowners, who will benefit from a dramatic increase in corn prices and associated increases in land rents. U.S. crop growers will benefit until the higher profits are captured by higher land values and land rents. Dairy and beef producers who are near ethanol plants will benefit from having access to DDGS. Owners of ethanol plants will benefit until corn prices rise to eliminate the current arbitrage in ethanol production.

Specialized pork and poultry producers who do not own shares in ethanol plants will lose, as higher corn prices, and eventually reduced international competitiveness, cause a reduction in production levels. The transition to these lower production levels will be painful for most of these producers. Ethanol construction will stimulate rural economies, as will the flow of profits from ethanol facilities. However, there will be a reduction in livestock in these same areas and this will eventually work to offset this advantage.

A standard argument in international trade is that while most trade arrangements have winners and losers, the successful agreements are so beneficial to the winners that they create enough surplus to help the losers adjust and adapt. An interesting policy question that we are in the process of addressing is whether the long list of positives associated with the expansion of corn-ethanol production is sufficient to offset the shorter list of negatives.

Endnotes

1. Some studies, including Von Lampe (2006), Ferris and Joshi (2005), and Gallagher et al. (2003), have investigated the implications of alternative developments in biofuels markets on world agricultural markets.

2. See, for example, Eidman (2005) or FAPRI (2006).

3. The modeling system we use is described at the following site: http://www.fapri.iastate.edu/models/. The models implicitly assume that consumers and producers respond to changes in price levels and relative prices in the future as they have been observed to do in the past. The specific models used in this analysis are the CARD international ethanol model, the FAPRI international sugar model, and modified or reduced-form versions of the FAPRI U.S. and international crop models. Livestock interactions are maintained in the crop models.

4. This is done with appropriate modifications to yields, as less desirable land comes out.

5. Ethanol from Caribbean Basin Initiative countries is allowed to enter the U.S. duty free.

6. Shurson (2004) has reported that with corn at $2.00 per bushel and soybean meal at $175 per ton, the value of DDGS in rations is as follows: $114.24 for dairy, $100.09 for poultry, $104.66 for layers, $96.34 for swine grower finisher, and $108.00 for beef feedlots.

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