

Long-Term and Global Tradeoffs between Bio-Energy, Feed, and Food

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<http://www.card.iastate.edu/publications/DBS/PDFFiles/07sr101.pdf>

Abstract

Projections of U.S. ethanol production and its impacts on planted acreage, crop prices, livestock production and prices, trade, and retail food costs are presented under the assumption that current tax credits and trade policies are maintained. The projections were made using a multi-product, multi-country deterministic partial equilibrium model. The impacts of higher oil prices, a drought combined with an ethanol mandate, and removal of land from the Conservation Reserve Program (CRP) relative to baseline projections are also presented. The results indicate that expanded U.S. ethanol production will cause long-run crop prices to increase. In response to higher feed costs, livestock farmgate prices will increase enough to cover the feed cost increases. Retail meat, egg, and dairy prices will also increase. If oil prices are permanently \$10-per-barrel higher than assumed in the baseline projections, U.S. ethanol will expand significantly. The magnitude of the expansion will depend on the future makeup of the U.S. automobile fleet. If sufficient demand for E-85 from flex-fuel vehicles is available, corn-based ethanol production is projected to increase to over 30 billion gallons per year with the higher oil prices. The direct effect of higher feed costs is that U.S. food prices would increase by a minimum of 1.1% over baseline levels.

Results of a model of a 1988-type drought combined with a large mandate for continued ethanol production show sharply higher crop prices, a drop in livestock production, and higher food prices. Corn exports would drop significantly, and feed costs would rise. Wheat feed use would rise sharply. Taking additional land out of the CRP would lower crop prices in the short run. But because long-run corn prices are determined by ethanol prices and not by corn acreage, the long-run impacts on commodity prices and food prices of a smaller CRP are modest.

Cellulosic ethanol from switchgrass and biodiesel from soybeans do not become economically viable in the Corn Belt under any of the scenarios. This is so because high energy costs that increase the prices of biodiesel and switchgrass ethanol also increase the price of corn-based ethanol. So long as producers can choose between soybeans for biodiesel, switchgrass for ethanol, and corn for ethanol, they will choose to grow corn. Cellulosic ethanol from corn stover does not enter into any scenario because of the high cost of collecting and transporting corn stover over the large distances required to supply a commercial-sized ethanol facility.

Keywords: biofuels, corn acreage, crop prices, ethanol production, food prices

Introduction

The recent emergence of biofuels as important agricultural products has generated interest in their likely impact on the rest of agriculture. Questions such as how large the ethanol and biodiesel sectors will become and their impact on corn and soybean markets have increased in importance as these sectors have grown. The large run-up in corn and soybean meal prices will have important impacts on the livestock sector and will eventually filter their way down to the consumer. Recognition of these impacts has created interest in the impact of biofuels on the livestock sector and on wholesale and retail prices.

The purpose of this report is to provide an estimate of how large the biofuels sector in the United States could become and to estimate the likely impact of this sector on crop markets, trade, and on wholesale and retail livestock markets.

This analysis builds on an October 2006 study by Elobeid et al. The fundamental insight in the Elobeid et al. study was that ethanol could be modeled like any other value-added agricultural product with investors willing to finance new construction so long as expected net returns are positive. This insight, plus the assumption that ethanol has a floor price at its energy value relative to gasoline, which is determined by crude oil prices, allowed calculation of a break-even corn price and the modeling of the impact of ethanol on the rest of agriculture.

For a \$60-per-barrel crude oil price (as measured by the U.S. refiners cost of acquisition for crude oil), Elobeid et al. calculated a break-even corn price of \$4.05. They then solved for the amount of additional U.S. ethanol production it would take to drive the U.S. corn price to \$4.05 and provided a preliminary indication of how U.S. and world agriculture would adjust to this level of U.S. corn output and corn price. The results suggested an annual U.S. ethanol output of slightly more than 30 billion gallons, with major reductions in U.S. soybean output, U.S. corn for exports, and U.S. corn domestic feeding stock.

The authors of the earlier study readily acknowledged some simplifications that they were forced to make. In particular, the modeling system that they used did not have any detail on the use of distillers grains in the diets of the various animal species in the United States and throughout the world. This meant that they could not report any species-specific impacts, nor could they calculate the impact on livestock prices. In addition, the study assumed that the prices of distillers grains would remain constant at baseline levels rather than be determined by

competition for feedstocks. A third assumption made was that all the ethanol that was produced would be sold so long as it was priced at or slightly below its energy value. This assumption made some sense given the long-run focus of the earlier work, but it ignores all the market and infrastructural bottlenecks that the ethanol industry will need to solve as market penetration grows.

In this study we address the weaknesses of the earlier study. We have added distillers grains to the models of the livestock diets in the United States and in the rest of the world. In addition, we have developed a detailed model of the U.S. market for ethanol.

Other changes to the earlier study include a reduction in the ethanol yield per bushel of corn from 3 gallons per bushel to 2.8 gallons per bushel. Industry sources have indicated that while 3 gallons per bushel is possible, it will involve the use of the seed pericarp and that this technology is not yet economical. We have also inflated the costs of operating ethanol plants to reflect the expected increases in labor costs in future years. We continue to ignore direct state and federal construction subsidies and state and federal tax credits. This assumption is conservative and implicitly provides the investors with a return on the risk they face when investing in a facility that may not start operations for two years.

One assumption from the earlier paper that we maintain here involves the wholesale-to-retail markup on ethanol. This markup is composed of transportation cost to the retailer, profit for the retailer, and state taxes. If we assume that the ethanol markup in cents per gallon is the same as that for gasoline, then we would implicitly assume that the markup on ethanol is higher when measured in percentage terms. To see why this is so, assume that the gasoline markup is \$0.25 per gallon and that wholesale gasoline also sells for \$2 per gallon so that the gasoline markup is 12.5% and retail gasoline prices are \$2.25 per gallon. Assume also that wholesale ethanol sells for its energy value of \$1.33 per gallon and that ethanol has a \$0.25 per gallon markup. Note that the ethanol markup is 15.1% whereas and that the gasoline markup is only 12.5%.

Given that a large portion of this markup consists of state taxes and that the likely sales area for ethanol will be in upper Midwestern states where ethanol is politically popular, it seems unlikely that states will charge a higher percentage tax on ethanol than on gasoline. In fact, all of the states that have visited the issue so far have actually worked to impose lower per-gallon taxes

on ethanol than on gasoline.² Therefore, we have assumed that the wholesale-to-retail markup on ethanol is the same *in percentage terms* as the markup on gasoline. The continued use of this assumption means that if ethanol sells at its energy value at retail pumps then it will also be priced at its energy value at the wholesale level.

As mentioned earlier, the Elobeid et al. study did not include any species-specific analysis of livestock. One problem that we encountered when we included livestock was how to project the impact of a dramatic increase in feed prices on livestock supply. The models that we use project behavior by assuming that market participants will respond in the future as they have in the past. For example, in the summer of 1995, U.S. corn prices went up dramatically because parts of the country were experiencing a temporary scarcity. Livestock growers could see a healthy corn crop in the fields and they could observe a futures market that predicted a low price after this crop was harvested. As a result, many livestock producers chose to ignore the short-term losses that they were experiencing and stay in business. We would not expect to see this kind of behavior in response to a permanent increase in feed prices but we do not have any historical evidence to base this on because we have not experienced a feed cost increase that livestock producers viewed as being permanent.

Defining Long-Run Equilibrium

As was true for the Elobeid et al. study, we use the concept of a long-run equilibrium to help us understand the eventual impact of the biofuels sector on agriculture. This concept is very intuitive. When we are at a long-run equilibrium, no group of producers or consumers has an

² States that have chosen to impose differential taxes on ethanol and gasoline (source:

<http://www.fhwa.dot.gov/ohim/mmfr/jul06/trmfuel.htm>):

Iowa—Effective 07/01/02, motor fuel tax rates will be adjusted annually based on the amounts of ethanol-blended gasoline being sold and distributed annually.

Minnesota—There is a credit to the wholesaler of 15¢ per gallon of alcohol used to make gasohol.

Montana—There is an alcohol distiller credit of 30¢ per gallon of alcohol produced in the state with state agricultural products and used to make gasohol.

Nebraska—Rates are variable, adjusted quarterly. The gasoline and gasohol include 0.6¢ per gallon. New Nebraska ethanol production facilities may receive an ethanol production credit equal to 18¢ per gallon of ethanol used to fuel motor vehicles.

North Dakota—There is a producer credit of 40¢ per gallon of agriculturally derived alcohol produced in the state and used to make gasohol.

Ohio—Dealers are refunded 10¢ per gallon of each qualified fuel (ethanol or methanol) blended with unleaded gasoline.

South Dakota—There is a credit at the rate of the gasoline tax to distributors blending gasoline with ethanol to product gasohol. There is also a producer incentive payment of 20¢ per gallon.

incentive to change its behavior. For example, if the ethanol industry is in equilibrium, then there is no incentive to build new ethanol plants and there is no incentive to shut down existing plants.

In response to increased demand for corn by the ethanol sector, feed prices increase and stay high for several years. We constrained the models to follow economic theory that shows that increased costs will lead to a reduction in supply and to a price increase so that net returns are once again at levels sufficient to keep livestock producers in business. This constraint was imposed on our baseline projections as well as on our analysis of various scenarios. This assumption forces the adjustment to ethanol by the livestock sector onto the wholesale and export markets and eventually to the retail consumer. It takes time for this adjustment to occur. We refer to model results that fully reflect these adjustments as the “long-run equilibrium.”

We imposed full price transmission of higher feed costs to Canada and Mexico, as well as to other countries where we expect this to occur. We did not impose full feed price transmission in other countries, such as the European Union and its feed wheat market, where trade barriers exist. The effect of this assumption was that the United States does not lose a significant amount of competitive advantage in international meat markets when U.S. corn and soybean meal prices increase. High U.S. feed prices cause high international feed prices, and the U.S. meat industry continues to have a cost advantage in meat production. If we were to run the model without this assumption, most of the adjustment of the livestock sector would be achieved through dramatic reductions in net exports, a result that assumes that the rest of the world somehow gains a competitive edge over U.S. livestock producers.

Differences between Results of the Two Studies

The report by Elobeid et al. was widely read, and it seems likely that many readers of this report will be familiar with the earlier report’s results. Therefore, it is worthwhile to summarize the key differences in the results. These are driven in large part by the inclusion of distillers grains (DG) in this study and by the model of ethanol demand that we now use.

Impact of the Inclusion of Distillers Grains on the Results

In the earlier work, a rapid increase in production of DG caused a reduction in soybean meal prices and a reduction in soybean prices. In the new model we find that DG enter the rations of ruminant animals, and that they replace corn mostly and soybean meal only to a limited extent.

With a large U.S. and international market for DG in ruminants, the DG price reflects its feed value in ruminant rations as a replacement for corn. This means that DG prices will track corn prices. Poultry and pork rations initially respond to a surplus of DG with relatively high inclusion rates, but as markets adjust and as DG prices rise, these species eventually revert to a corn-soybean meal diet.

The inclusion of DG in the model produces some profound and somewhat counterintuitive effects. For example, we had originally assumed that the impact of the ethanol boom would be lower for beef producers than for hog and poultry producers because DG can more readily be included in ruminant rations than in hog and poultry rations. Instead, because DG prices track corn prices, the impact on cattle feed is as great as the impact on hog feed.

With more expensive DG, world poultry and swine producers continue to purchase corn and soybean meal and thus soybean prices increase rather than decrease. This increase in soybean prices causes South American soybean acres to increase substantially as the United States reduces its soybean production. In Elobeid et al., South America turned from soybean production to corn production, and by the end of the period the United States was importing a small amount of corn. In this report, the United States continues to export corn because South America concentrates on soybean production.

Impact of Adding an Ethanol Demand Component to the Model

As mentioned earlier, Elobeid et al. simply assumed that the U.S. ethanol industry could sell all of its production on the U.S. market at its retail energy value. Because the amount of ethanol that was projected to be produced was much greater than that needed for a nationwide E-10 blend, this meant that as much as 50% of the ethanol was projected to be consumed via E-85 blends.

When we added an ethanol demand component to this study, we included a careful analysis of the number and location of existing and new flex-fuel vehicles (FFVs). We also made the number of FFVs responsive to the price of ethanol relative to its energy value. This analysis showed that the projected number of FFVs in key Midwestern states (where ethanol would be cheapest relative to gasoline) was insufficient to consume the projected 30 billion gallons of ethanol.

There is a chicken-and-egg problem with E-85. It will only pay for gas stations to install E-85 tanks and pumps and for consumers to purchase FFVs or convert existing cars to run on E-85 if ethanol sells at a significant discount to gasoline. But if ethanol sells at such a discount it does not pay to build new ethanol plants. We refer to this problem as the “E-85 bottleneck,” and we include this bottleneck in our baseline results.

Note that the E-85 bottleneck results are in equilibrium in that it is not in the interests of any party to change their behavior. Gas stations do not see any reason to add E-85 pumps and most consumers do not see any reason to buy E-85 cars. The ethanol sector expands until it has driven the price of ethanol below its energy value relative to gasoline and then it stops expanding. At the end of the projection period the ethanol sector breaks even. Corn prices gradually fall back to reflect the lack of new ethanol facilities coupled with increased corn yields.

A second impact of adding ethanol demand to the model is that once the plants that are currently under construction are completed, we can then use the model to understand ethanol supply decisions. We assume that this occurs in 2010, at which time we model possible future plant construction by looking at an investor who is considering an investment in a new ethanol plant.

One factor that we do not account for in this study is the possibility that expanded ethanol production will impact the price of gasoline. If ethanol captures a significant share of the U.S. fuel supply, it may begin to affect oil refiners’ margins and their subsequent decisions about which products to produce and the prices of those products.

Methodology

As was true for the earlier paper by Elobeid et al., we use a very broad model of the world agricultural economy to evaluate the likely impact of biofuels growth on agricultural markets. The system that we use is a customized version of the deterministic Food and Agricultural Policy Research Institute (FAPRI) modeling system that contains models of supply and demand for all important, temperate agricultural products in all relevant counties.

For any crude oil price we calculate the price of unleaded gasoline. This price, along with the capacity of the ethanol industry, determines the price of ethanol (adjusted for the blender’s credit) and the incentive to invest in additional ethanol production capacity. Ethanol production determines the demand for corn. Investment in new ethanol plants will take place if the market

price of corn allows a prospective plant to cover all the costs of owning and operating an ethanol plant. Long-run equilibrium prices for ethanol, crops, and livestock are achieved when there is no incentive to construct new plants, no incentive to expand or contract livestock production, and all crop markets clear.

We are aware of only one set of commodity models that have the required multi-commodity, international coverage to allow all of the various interactions that are needed for this study. These models are developed and operated by FAPRI analysts. We have customized these models to examine how world agriculture will respond to the set of prices that will cause the agricultural energy sector to stabilize.³ Elobeid, Tokgoz, Yu, Dong, and Fabiosa are responsible for developing and maintaining the FAPRI international models for sweeteners, grains, oilseeds, dairy, and livestock.⁴

The Importance of Crude Oil Prices

In the Elobeid et al. study, for every \$0.10 increase in the market value of ethanol, the break-even corn prices in our model increase by \$0.28.⁵ This means that relatively small changes in ethanol prices will have a very large impact on the price of corn and, by extension, on agriculture. We model ethanol demand based on gasoline prices and ultimately on crude oil prices. A \$0.10 increase in the retail price of gasoline is not unusual, but a \$0.28-per-bushel permanent increase in corn prices is an unusual event and would cause an increase in cash rents of about \$50 per acre on good corn land. This extreme sensitivity to crude oil prices becomes readily apparent in our results. Figure 1 shows how 2012 crude oil futures prices have moved over the last year. They have ranged from a low of below \$52 per barrel to a high of over \$70 per barrel.

³ Because FAPRI uses a set of stochastic models to analyze changes in U.S. and world farm policies when requested to do so by members of Congress, if FAPRI were to conduct this analysis using their stochastic models, they would come up with somewhat different estimated impacts. See the FAPRI Web site for a description of the models: www.fapri.iastate.edu.

⁴ FAPRI is a joint effort of Iowa State University's Center for Agricultural and Rural Development (CARD) and the University of Missouri-Columbia. FAPRI utilizes a set of interrelated supply and demand models to estimate the impacts of changes in policy and economic parameters on prices and production levels of important agricultural commodities in major importing and exporting countries. FAPRI analyses of the impacts of U.S. policy changes on the U.S. agricultural sector are conducted using stochastic models. A separate set of deterministic models is used to perform the work described here.

⁵ Assuming that all else is held constant.

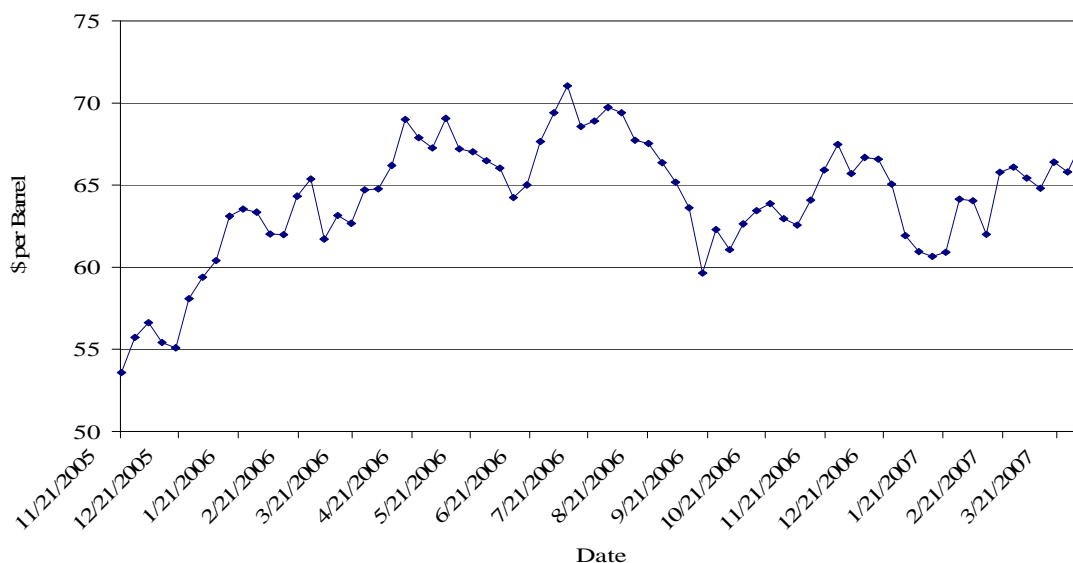


FIGURE 1. Weekly closing prices on the NYMEX light sweet crude futures for delivery in December 2012

To demonstrate the impact of an increase in crude oil prices over the level that is used in the baseline projections, we ran a scenario whereby crude oil prices are \$10 higher for each year of the projection period. As will be shown, this increase in crude oil prices dramatically increases the investment in ethanol production. Under the assumption that the E-85 barrier is eliminated, this increase in crude oil prices increases projected ethanol production from corn by 15 billion gallons.

The equilibrium corn price in the baseline scenario is \$3.16 per bushel. The soybean meal price is \$158 per ton. The equilibrium corn price with higher oil prices and without the E-85 barrier is \$4.42 per bushel, with a soybean meal price of \$193 per ton. These prices suggest a relatively large difference in animal feed ration prices and therefore provide a good basis against which to evaluate the impact of ethanol on the livestock sector and on retail prices.

Therefore, the discussion of the impact of ethanol on the livestock sector is framed in terms of the impact of a move from an industry supplying approximately 15 billion gallons of ethanol in the baseline to a 30-billion-gallon ethanol industry under quite optimistic economic conditions for the ethanol industry.

We also analyze a scenario in which the E-85 bottleneck is maintained with higher crude oil prices. The results of this scenario suggest an ethanol industry of 22 billion gallons, which is about halfway between the baseline and the optimistic scenario. These results are not reported

here because they show an impact of almost exactly half those shown in the optimistic scenario.

Our results also provide projections for the biodiesel sector. These results are not nearly as large as for the ethanol sector. When crude oil prices increase, the price of biodiesel also increases. However, an increase in crude oil prices dramatically increases corn acres in the long-run. The resulting reduction in soybean acres drives up soy oil prices and, by extension, the prices of other oils and fats. This increase in soy oil prices dampens the incentive to expand the biodiesel sector.

The intuition behind the large response of ethanol relative to biodiesel is as follows. Midwestern crop growers choose between planting corn and soybeans with appropriate penalties for continuous corn. The models allow energy prices to influence this choice. Given these incentives, many farmers choose corn over soybeans because an acre of corn provides more energy value than an acre of soybeans. This suggests that, under this framework, the biodiesel sector will not grow substantially without a change in the structure of subsidies under reasonable assumptions about energy values of soybeans relative to corn.

In the results that follow, we show the baseline results by year to provide a sense of the dynamic impact of this industry and to differentiate between the impacts of plants that are currently under construction from those that may or may not be built. We present the results for the livestock sector by comparing the long-run equilibrium results from the baseline and for two analyzed scenarios. We do this because it is important to allow the livestock sector to adjust and because this adjustment is not completed until the last year of each scenario. Retail price impacts are presented and discussed in the context of the livestock sector adjustments.

Baseline Projections

Energy Markets

The modeling system that we use relies on the acquisition cost of crude oil in the United States. This price is typically lower than the U.S. light sweet crude price that is traded on futures markets (NYMEX). The price difference between the two price series, shown in Figure 2, has averaged approximately \$6.70 per barrel over the period shown.⁶ We subtract \$6.70 from NYMEX prices to obtain the crude oil price projections for this analysis. This basis results from

⁶ The average price difference is dependent on the time period used. Looking back to the beginning of 2003, the average price difference was lower, at approximately \$5.00 per barrel.

the lower quality of crude typically imported into the Gulf of Mexico and transportation costs.

When we ran the baseline scenario, the NYMEX price for delivery in December 2012 was \$64.50 per barrel. This corresponded to a unit import price of \$57.80 for 2012. The only source of energy price projections beyond 2012 is the Department of Energy, and they were projecting a \$3.50-per-barrel price decline from 2012 to 2016. This brought our baseline price forecast down to \$54 per barrel by the end of the period (Figure 3). The last year's price is critical because it is the price we use to find the long-run equilibrium.

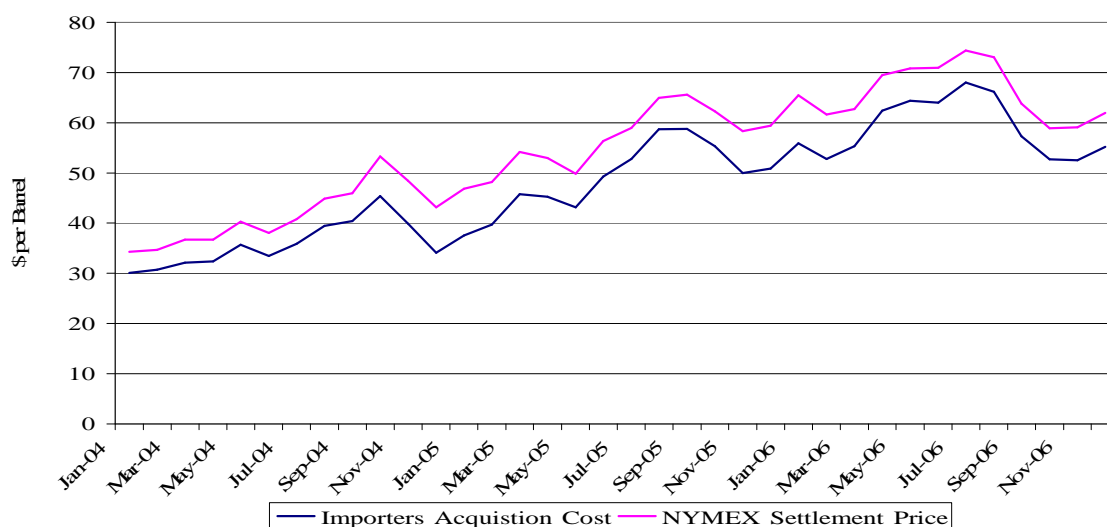
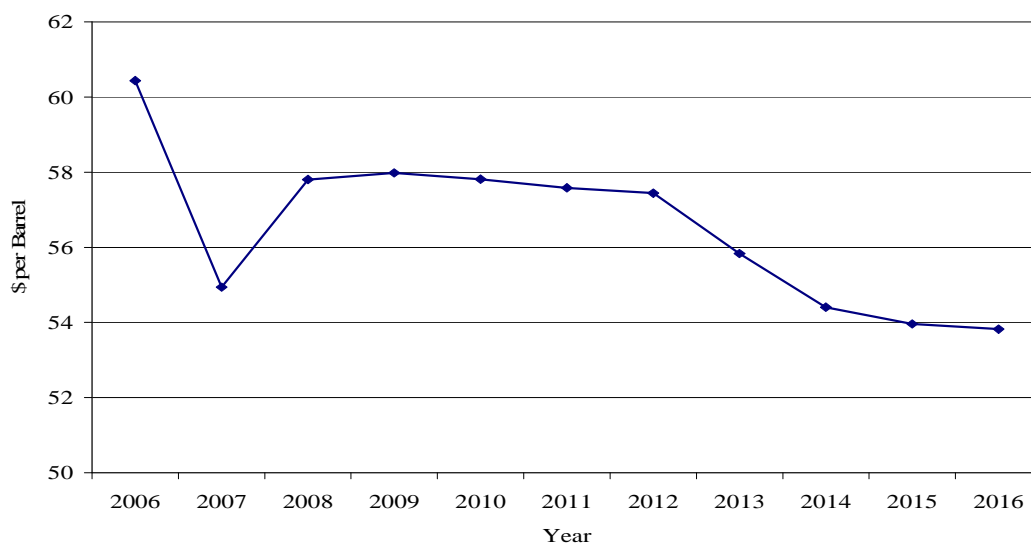


FIGURE 2. Recent crude oil prices



Note: Data based on December NYMEX crude oil futures prices to 2012 and extended to 2016 using Department of Energy projected oil price changes.

FIGURE 3. Projected imported crude oil acquisition prices

Figure 4 shows the price for gasoline and ethanol in our baseline projections. The gasoline price is calculated as a proportion of the crude oil price. The ethanol price is solved in the model after taking into account the amount of ethanol that is produced and consumed. This ethanol price data includes the \$0.51-per-gallon blender's credit. As shown, the projected expansion in ethanol production drives down ethanol prices below the price of gasoline, where they remain throughout the projection period. The reason why ethanol prices fall significantly below the price of gasoline is that we assume that consumers are rational and realize that ethanol has lower energy value than gasoline so that a E-10 blend will have to sell for less than gasoline at increased production levels. Thus, the price of ethanol must fall so that blenders will choose to include it in their blends and consumers will choose to use the blended fuels.

By the end of the period, the wholesale price of ethanol is \$1.57 per gallon. When we subtract the blender's credit, the effective price to the blenders is \$1.06 per gallon. The

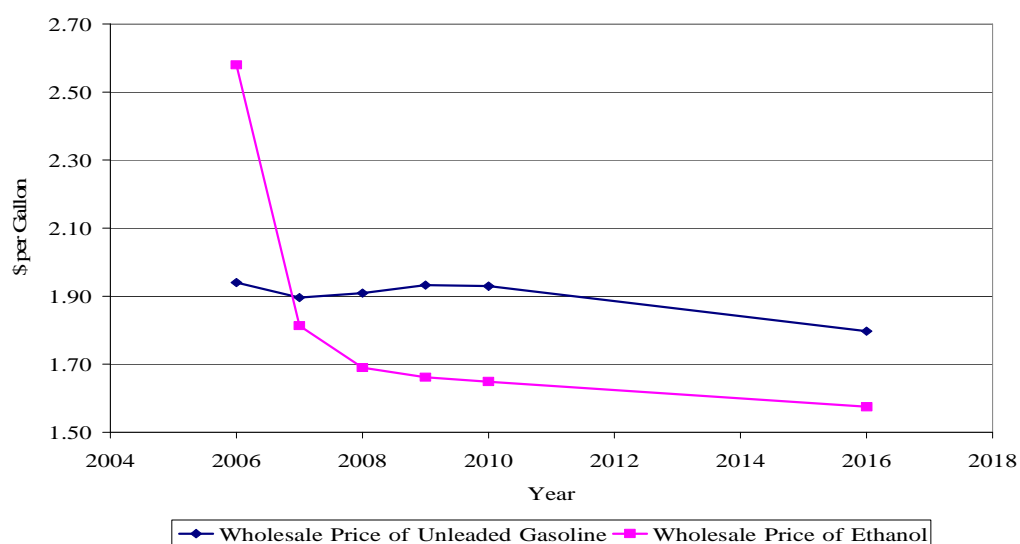


FIGURE 4. Projected gasoline and ethanol prices

end-of-period wholesale price of gasoline is \$1.80 per gallon. This means that ethanol is selling at about \$0.14 per gallon below its energy value of \$1.20 per gallon. These results indicate that ethanol demand becomes the limiting factor to the growth of the ethanol sector. As production increases, the price of ethanol has to fall relative to its energy value to entice gas stations and car owners to purchase the product. These low prices eventually halt the expansion of the sector.

Figure 5 shows projected margins for dry-mill ethanol plants. The plants always cover their variable costs but they do not cover their full costs for most of the period. We assume that equilibrium is achieved in 2016 so investors are indifferent between building and not building a new ethanol plant. This indifference occurs because the ethanol industry stops growing in response to earlier negative earnings. Higher corn yields eventually allow the price of corn to fall so that this equilibrium condition is achieved.

Corn and Soybean Markets in the Baseline

The next set of results show how corn and soybean markets respond in the baseline projections. As mentioned earlier, ethanol production continues to grow until the plants that are currently under production have come online in early 2010. Then growth stops as ethanol prices fall below their energy value. At this point the size of the ethanol industry is slightly in excess of 14 billion gallons (Figure 6) and the annual corn grind is slightly in excess of 5 billion bushels. This relatively large quantity of corn for ethanol is obtained by shifting U.S. crop acreage from other crops to corn production and by reducing U.S. corn exports and corn fed to livestock (Figures 7–9). The drop in U.S. soybean production is offset by increased South American production. As corn yields grow toward the end of the projection period, markets are eventually able to adjust to this ethanol grind, and market prices begin to revert to more normal levels (Figures 10 and 11).

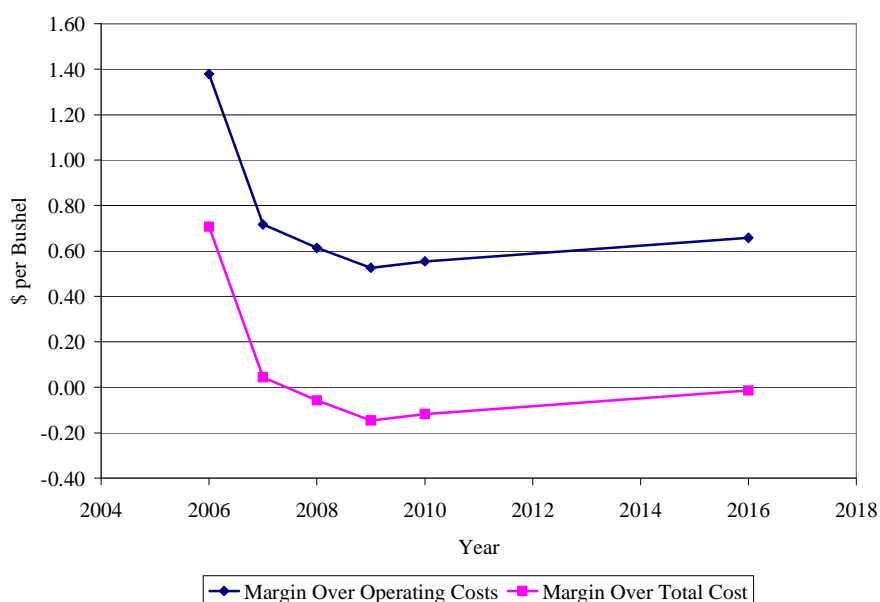


FIGURE 5. Projected U.S. dry mill margins over operating costs and over total costs

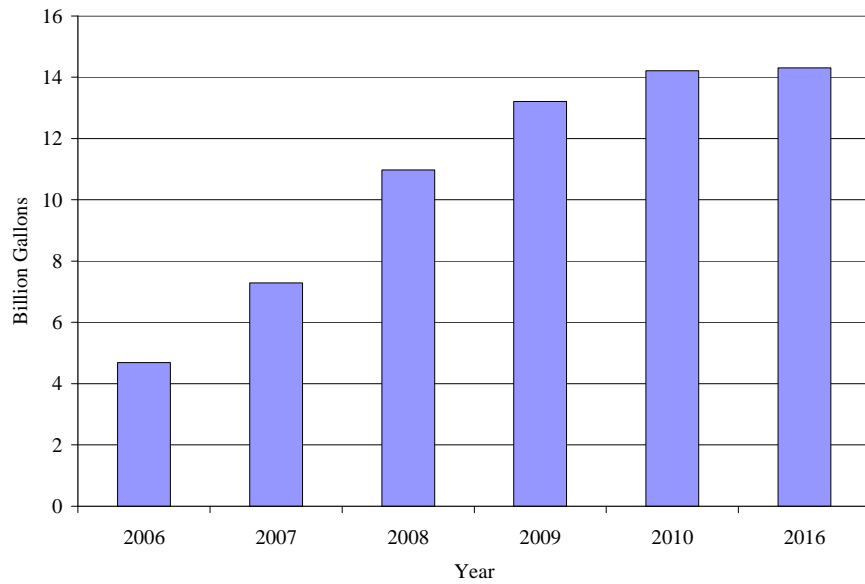


FIGURE 6. Projected U.S. ethanol production from corn

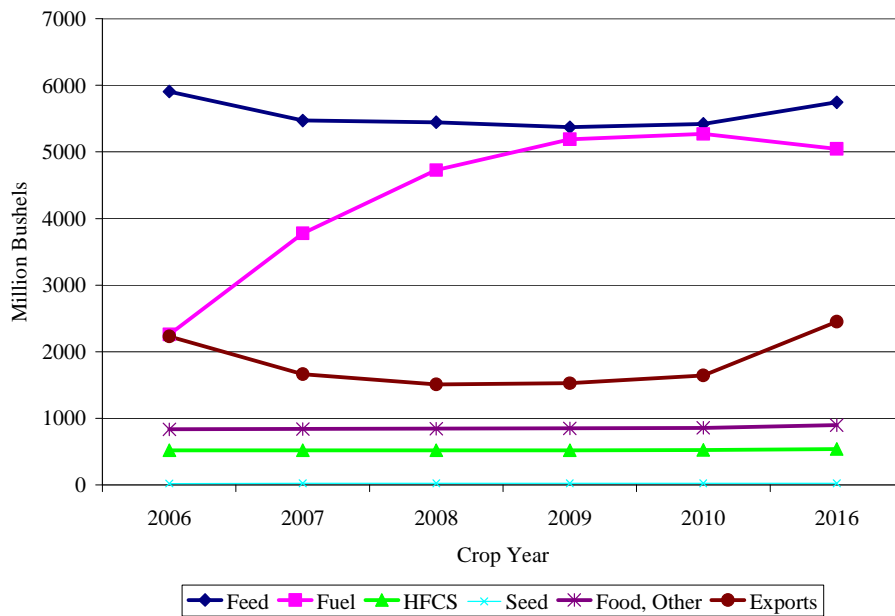


FIGURE 7. Projected utilization of corn in the United States

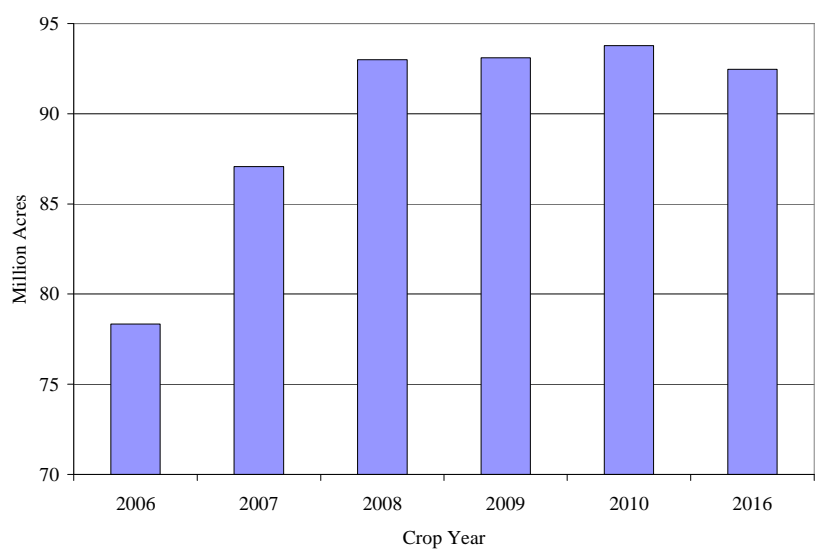


FIGURE 8. Projected U.S. corn planted area

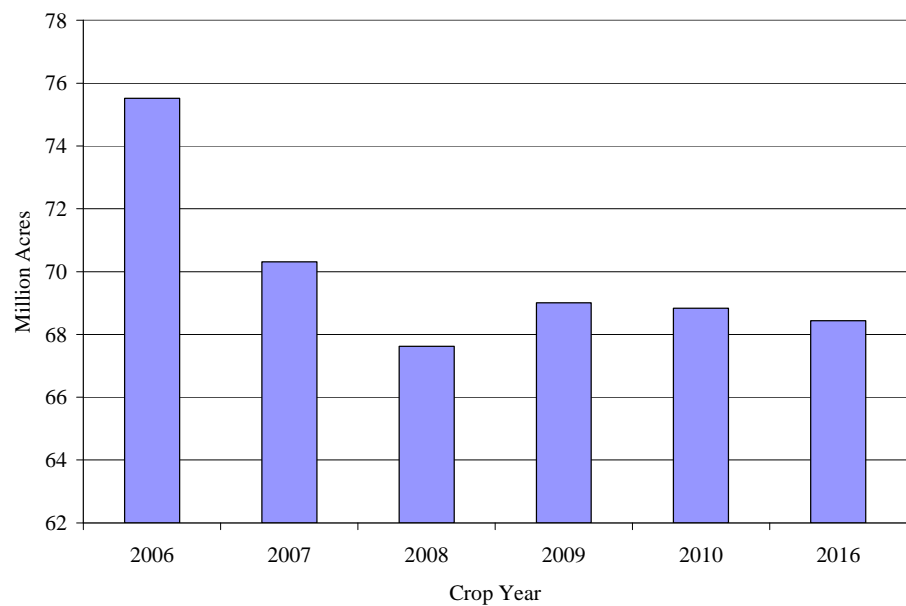


FIGURE 9. Projected U.S. soybean planted area

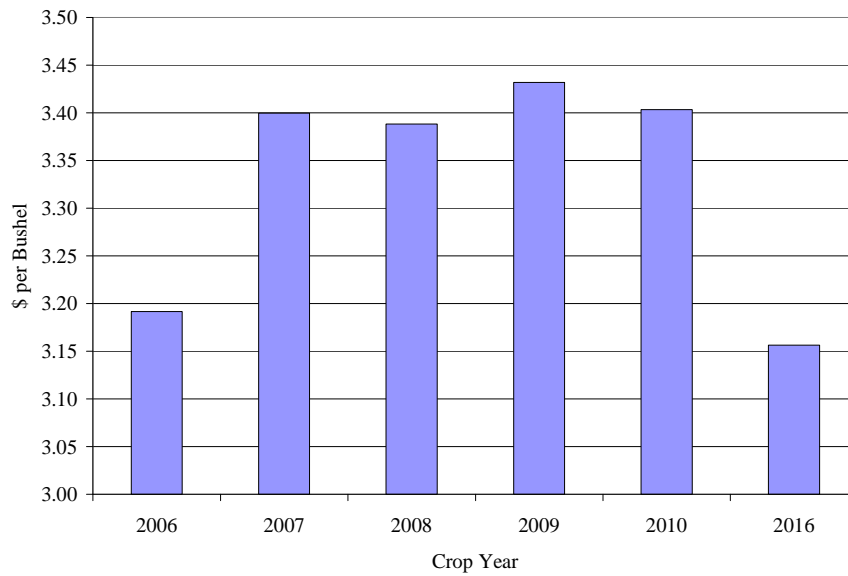


FIGURE 10. Projected U.S. corn prices

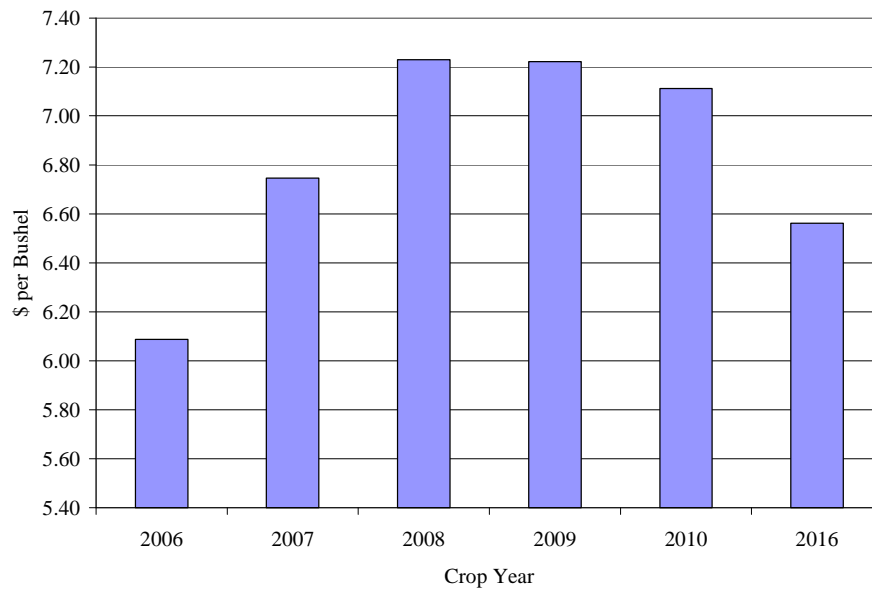


FIGURE 11. Projected U.S. soybean prices

Distillers Grains in the Baseline

As it became clear that the ethanol industry was experiencing a period of rapid growth that would in turn provide a large supply of DG, it also became clear that livestock feeders would find a way to incorporate this product into their feed rations. Elobeid et al. implicitly assumed that the increase in supply of DG would tend to hold down DG prices and benefit the ruminant sector relative to other species. We based this conclusion on work by Shurson

(2004), who reported that with corn at \$2.00 per bushel and soybean meal at \$175 per ton, the value of DG 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.

Our results here indicate that U.S. and world ruminant demand is strong enough to cause the prices of DG to track corn prices. This means that the cost of rations that contain DG instead of corn increase by almost as much as rations that contain no DG. In other words the presence of large quantities of DG does not confer any particular benefit to any species. Faced with high DG prices, non-ruminant rations eventually revert to a corn and soybean meal diet, and this helps maintain price strength in the soybean market. South American crop growers respond with a dramatic expansion of soybean acres. The earlier report suggested far more corn acres in South America and even suggested that South America would be in a position to export a small amount of corn to the United States.

Figure 12 shows the projected increase in U.S. DG production. The amount of DG projected to be fed to beef, pork, poultry, and dairy is shown in Figure 13. It is clear from these projections that the U.S. beef sector is by far the dominant user of this product. This result implicitly assumes that the DG product will be transported from DG surplus areas in the Corn Belt to cattle feeding states such as Oklahoma and Texas. We are aware of problems with the transportation of this product that will need to be resolved before shipments of this magnitude can occur.

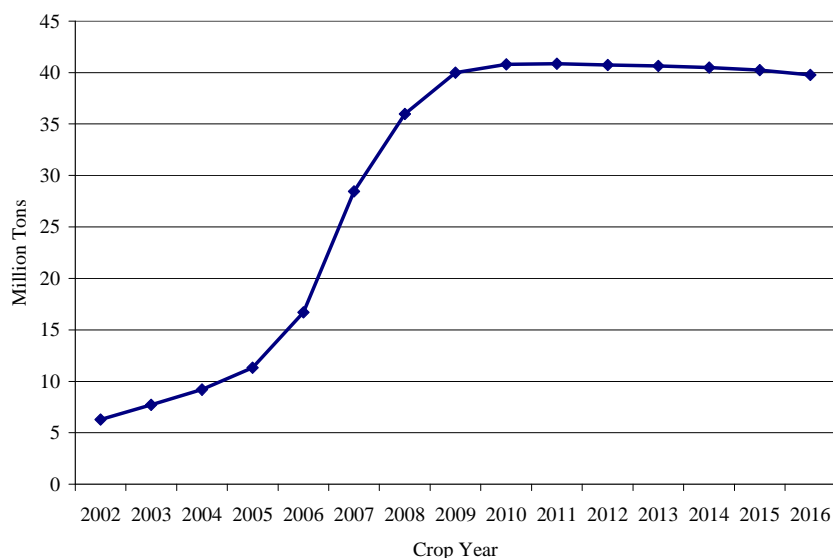


FIGURE 12. Actual and projected distillers grains production in the United States

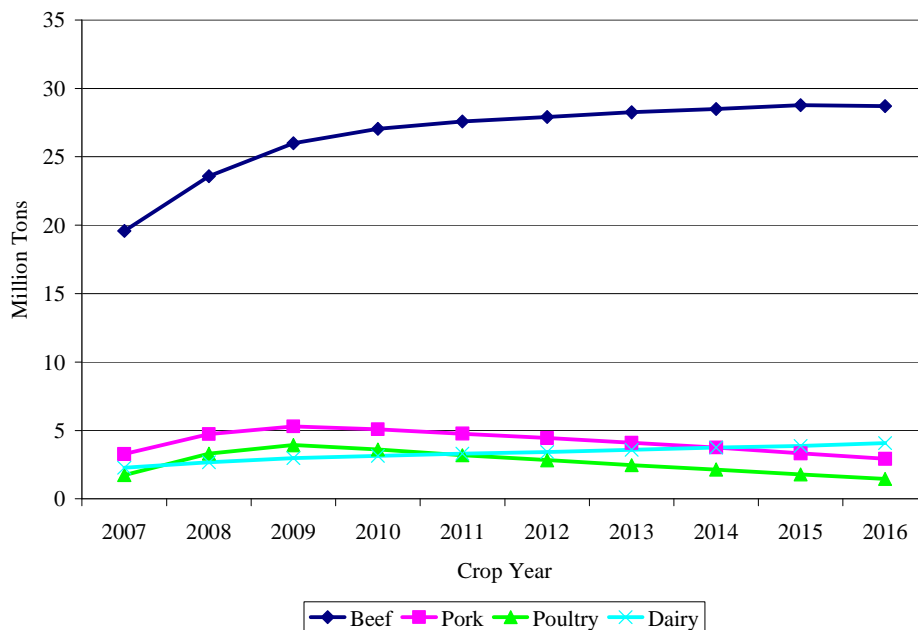


FIGURE 13. Projected use of distillers grains in U.S. feed

As shown in Figures 14 and 15, the model assumes a maximum inclusion rate in pork and poultry rations of 20% in 2007, and for poultry the maximum inclusion rate rises to 25% over time. As shown, projected DG consumption never comes close to this maximum inclusion rate and in fact falls off dramatically in the outer years. Figure 16 shows DG prices relative to corn prices. DG prices lag behind corn prices in 2007 but they catch up in later years. This result seems counterintuitive given the enormous increase in projected DG output and media reports of free DG available at ethanol plants. However, for every 17 pounds of DG that must be sold on the market about 56 pounds of corn must be taken off the market to produce the ethanol. The ruminant animals that would have consumed these 56 pounds of corn utilize the DG by-product instead. This price comparison helps explain why the pork and poultry industries typically avoid the product. It would take a major price reduction to make it worthwhile to utilize this product in non-ruminant rations, and this price discount does not occur.

Figures 17 and 18 show the projected impact of increased production of U.S. ethanol on South American soybeans. As shown, South American soybean production is projected to ramp up substantially in response to higher soybean prices and the drop in U.S. soybean production.

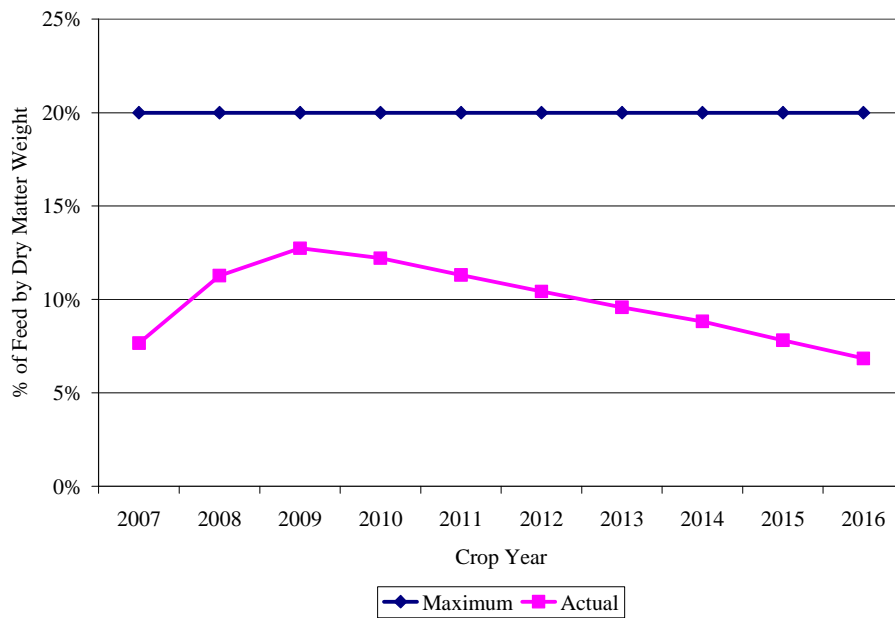


FIGURE 14. Maximum and projected actual inclusion rates of distillers grains in pork feed

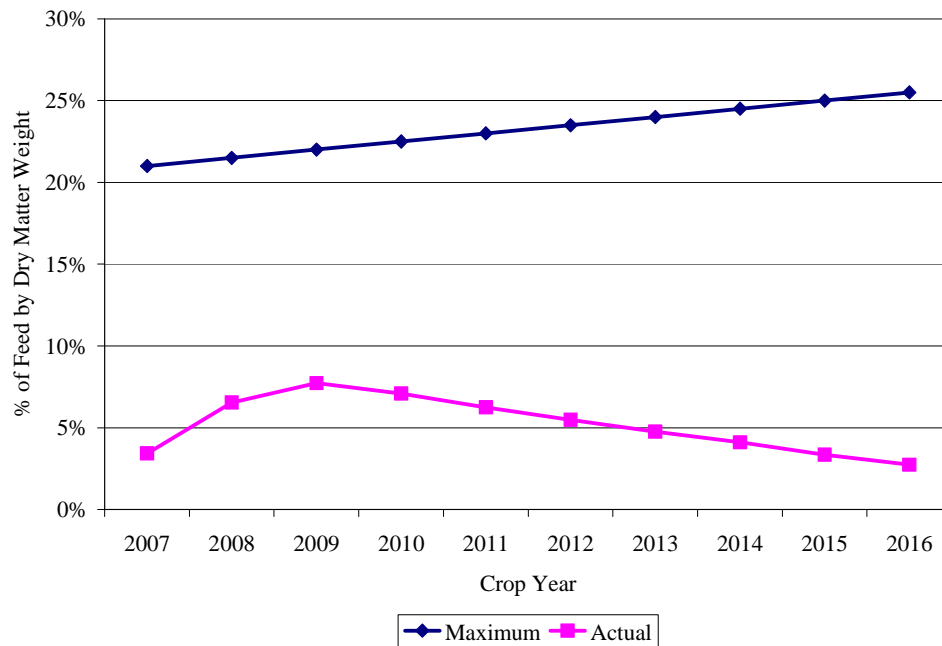


FIGURE 15. Maximum and projected actual inclusion rates of distillers grains in poultry feed

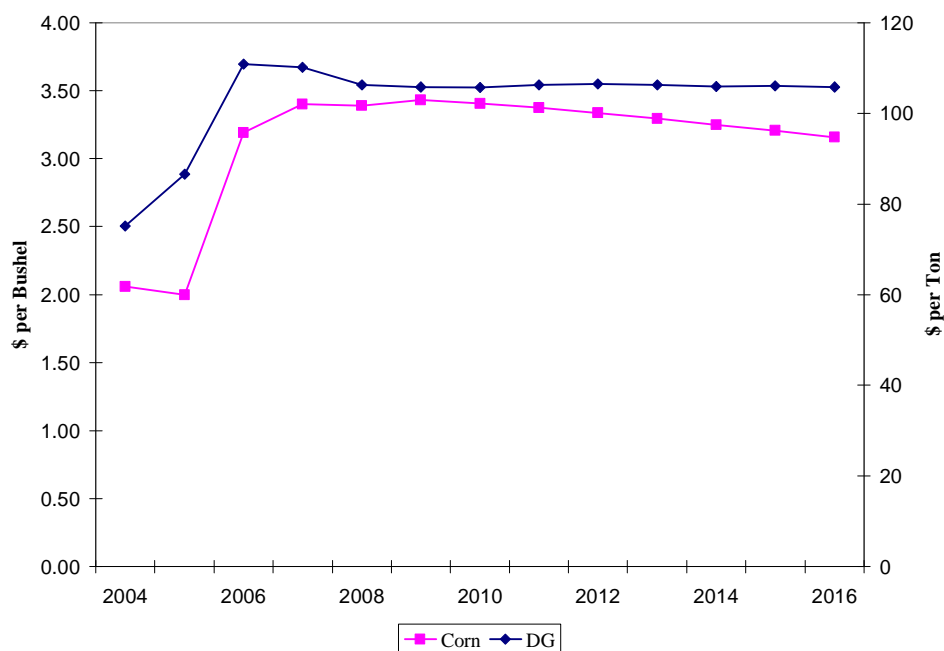


FIGURE 16. Relationship between corn and distillers grains prices

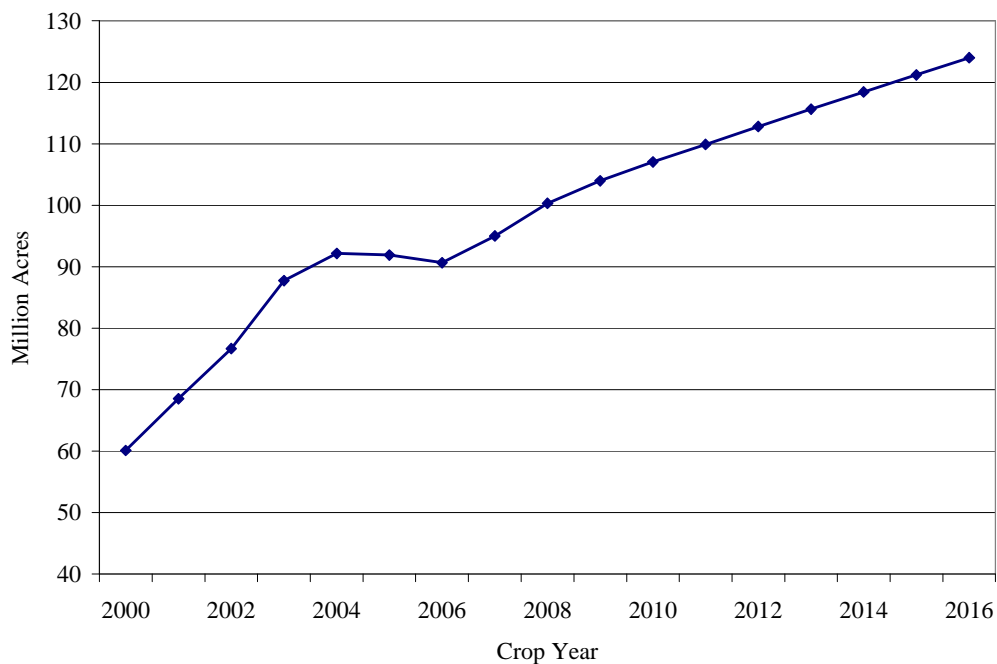


FIGURE 17. Brazilian and Argentine soybean planted area

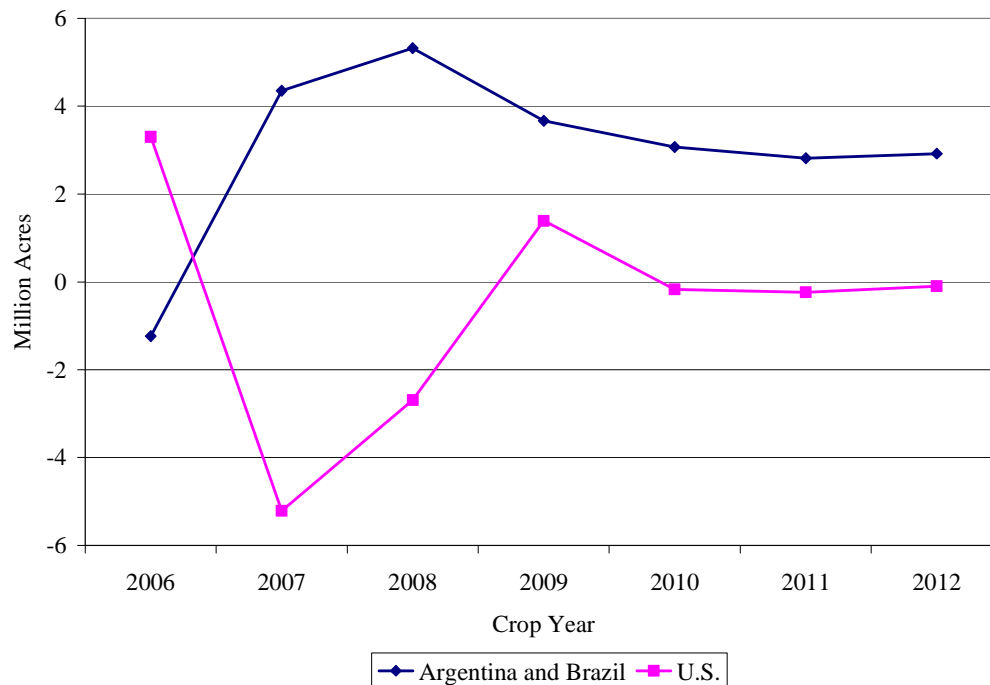


FIGURE 18. Projected annual changes in South American and U.S. soybean planted area

Scenario Results

The three scenarios presented in this report are (1) higher oil prices (oil plus \$10) with no E-85 bottleneck, (2) a short-crop projection using 1988 drought data with a high ethanol mandate, and (3) an additional seven million acres taken out of the Conservation Reserve Program (CRP). The three scenarios are presented relative to the baseline projections. Appendix tables A available on the web (<http://www.card.iastate.edu/publications/DBS/PDFFiles/07sr101.pdf>) compare the long-run equilibrium results for the baseline, and two scenarios (oil plus \$10 with no E-85 bottleneck, and reduction in CRP acres), for U.S. crops and livestock. The short-crop scenario leads to long-run equilibrium results similar to the baseline. Detailed results for each scenario, each year, and for other countries are available in a separate Appendix B (available at http://www.card.iastate.edu/publications/DBS/PDFFiles/07sr101_appendix-b.pdf).

In addition to the three scenarios reported here, we have run two other scenarios, including what would happen if the ethanol tariff were removed; and what would happen under higher oil prices but with lack of growth in flex-fuel cars limiting ethanol demand. The results of these scenarios will be reported in detail in a subsequent study.

Before moving to a discussion of the scenario results, it is important to understand some key underlying assumptions that drive the results.

- **Trend Yields:** Changes in acreage will not affect crop yields. Projected corn acreage ranges from 95 million acres to 112 million acres but corn yields are unchanged. If, instead, we had allowed corn yields to decline, and soybean yields to increase, then the supply curve of corn would be more inelastic than the results suggest. A more inelastic supply curve would mean fewer corn acres planted and a smaller ethanol industry. However, because the price of corn is determined by gasoline prices, corn prices would be unchanged.
- **Meat Quality:** Changes in feed rations will not affect meat quality if actual inclusion rates are less than maximum inclusion rates. There have been reports that high feeding rates of DG to cattle may affect marbling characteristics. If meat quality suffers then the demand for DG from cattle feeders would be lower than that assumed here. Lower demand translates into a lower price and subsequent lower margins for ethanol plants and a lower break-even price of corn. This lower corn price would then reduce corn acreage and the size of the ethanol industry.
- **Transportation:** All transportation bottlenecks will be solved. Transportation constraints on the movement of ethanol, DG, fertilizer, and corn could play an important role in determining where future ethanol plants will be located. If, for example, the problems with transporting DG from surplus areas in the Corn Belt to deficit areas in the High Plains are not solved, then it is likely that either ethanol production will begin to migrate to the cattle or cattle will begin to migrate to the Corn Belt.
- **Permanent versus Temporary Price Shocks:** Crop price increases caused by expansion of ethanol production are assumed to be permanent. Thus, the livestock industry is assumed to adjust production levels to maintain profitability. Crop price increases caused by a short crop are assumed to be temporary so that the livestock industry only makes short-run production adjustments as needed. Thus, the livestock price increases caused by a temporary shock will be lower than those caused by a permanent shock.
- **Ethanol from Cellulose:** This study only assesses the relative profitability of producing ethanol from corn, corn stover, and switchgrass grown in the Corn Belt. Because ethanol from corn is the only one of these three sources to generate positive returns, it is the only one that we include in our baseline and scenarios. Other sources of ethanol from cellulose may prove more feasible.
- **Food Price Limitations:** This study only assesses the impacts of ethanol on food prices from the direct effects of higher feed costs on livestock. We do not measure food price increases from high fructose corn sweeteners or the effects on fruit and vegetable supplies from increased competition for land from corn. In addition, food price increases are assumed to be set in perfectly competitive markets. This assumption implies that higher feed prices travel through supply chains in fixed, whole-dollar amounts. If instead higher feed prices move through in fixed percentage terms, then food price increases would be greater than reported here. As such, this study likely understates the actual impact on food prices from ethanol.

The baseline and the oil-plus-\$10 scenario probably represent the upper and lower bounds of the size and impact of ethanol, and therefore the differences across them provide a very clear indicator of the impact of this industry on other sectors. The ethanol grind in the baseline scenario is approximately 5 billion bushels, which doubles under higher oil prices. The corn price in the baseline is \$3.16 per bushel, and in the scenario it is \$4.43 per bushel.

Note that the total impact of the ethanol industry on livestock is greater than what is reported in the oil-plus-\$10 scenario because the corn price in the baseline is at \$3.16, well above the corn price that was typical before the ethanol boom began. The impacts of taking an additional seven million acres out of CRP are ultimately smaller than expected. Additional cropland initially depresses corn prices. Lower corn prices result from additional supplies of corn to provide feedstock for ethanol plants and livestock feeders. These lower corn prices could occur in the rapid-growth stage of ethanol production, thereby alleviating some of the financial stress on livestock producers during this period. However, this policy change does not have a significant impact on the long-run break-even price of corn for use in ethanol facilities, which means that the impact on livestock and retail meat prices will be small relative to the baseline.

Results for all the livestock species follow a similar pattern. Feed prices increase dramatically, as do livestock farmgate prices. For example, an increase in the corn price from \$3.16 to \$4.43 and a \$34.23-per-ton increase in the soybean meal price result in an 18.4% increase in the cost of producing pork and an 18.4% increase in live hog prices. This relatively large live hog price change leads to a relatively small increase of 4.2% in retail pork prices. The assumption that we use to set retail prices are that per-unit feed cost increases are passed through intact through the meat supply chain. Thus, as the ratio of feed cost to total value at each point in the supply chain decreases, so too does the percent change in price from ethanol. Per capita pork consumption falls by 2% and pork exports fall by 17%. Total pork production falls by 4.6%. The impact on the retail price is small because none of the other costs associated with processing, transporting, and retailing pork is impacted by ethanol. Per capita pork consumption does not respond very strongly to a retail price increase because the prices of all livestock products increase by similar amounts at the same time. Pork exports fall because worldwide pork consumption falls slightly in response to higher pork prices and because the United States loses a small part of its competitive position relative to the European Union.

Results for beef, poultry, eggs, dairy products, and turkeys all follow similar patterns, as shown in the tables in Appendix A and Appendix B (provided in a separate document). Overall retail meat and dairy product prices increase by approximately 5%. Note that if we had included the full impact of ethanol starting with a \$1.90 corn price and increasing to \$4.43 with a proportionate increase in soybean meal prices, then the retail price impact would be approximately 10%. Again, this impact on retail price levels seems surprisingly small given the enormous upheavals in the livestock feed sector. But a 10% increase in retail prices for affected products is a large and unforeseen increase in the cost of living.

Table 1 shows the effect on food prices of the scenario for crude oil plus \$10, no E-85 bottleneck, relative to the baseline and relative to an assumed “no-ethanol” corn price of \$1.90. From the baseline, egg prices increase by approximately 8% and poultry prices increase by approximately 5%. Other meat and dairy prices increase by slightly smaller percentages. Overall consumer expenditures on food would increase by about \$40 per person from the baseline and by about \$67 from \$1.90 corn.

Price Effects to Date

The model calculates the market-clearing price in each year based on expected supply and demand conditions in that year. The model does not contain equations that describe the kind of speculative storage that drives the intertemporal basis on futures markets. What appears to have happened this year is that futures traders have anticipated higher long-run corn prices and have begun to build these high prices into nearby futures contracts. They can do this because corn can be stored from year to year. This means that most of the long-run price changes we anticipate have already shown up in market prices. If we take the price increase that we have seen since July 2006 of approximately \$1.50 per bushel in corn and associated price increases in soybeans and wheat, the per capita increase in food costs is approximately \$47. Multiplying this cost by 300 million American consumers gives us a total cost of ethanol of about \$14 billion. In addition, taxpayers have contributed \$0.51 per gallon of ethanol.

TABLE 1. Percent change in food prices between baseline and “high-oil, no-bottleneck” scenario and between “no-ethanol” and “high-oil, no bottleneck” scenario

Food Item	Percent Change	
	Baseline to High Oil	No-Ethanol to High Oil
ALL FOOD	1.1	1.8
Food at Home	1.3	2.2
Cereal and Bakery	0.7	1.2
Meat	3.8	6.3
Beef	4.1	6.8
Pork	4.5	7.5
Poultry	5.1	8.5
Eggs	8.1	13.5
Fish	0.0	0.0
Dairy	2.1	3.5
Milk	2.7	4.5
Cheese	2.3	3.8
Ice Cream	0.8	1.3
Fruit and Vegetables	0.0	0.0
Other Food At Home	0.3	0.5
Sugar and Sweets	1.4	2.3
Fats and Oils	1.0	1.7
Other Prepared Items	0.0	0.0
Non-alc. Beverages	0.7	1.2
Food Away From Home	0.9	1.5

Because world feed prices track U.S. feed prices, the rest of the world’s consumers would also see higher food prices. To the extent that both feed and livestock markets are closely integrated in all countries, the food price increases reported for the U.S. consumer would also be felt by the rest of the world. However, consumers in the rest of the world tend to spend a lower proportion of their food dollar on meat and dairy products relative to the U.S. consumer. Hence, the percent increase in food prices would tend to be less. In addition, many countries do not have free trade in either meat or feed grains, so trade barriers would need to be accounted for to obtain a good estimate of the impact of U.S. ethanol on world food prices.

Three Caveats

Note that we are modeling the direct effect of feed cost increases on food costs. That is, we assume that livestock producers and retailers pass along only the additional feed cost and that they do not add any other cost increases. Were we to assume that the livestock marketing chain passed along price increases in percentage terms rather than in dollar terms, then the price effect would be much larger. Moreover, we do not account for any food cost changes from other land-intensive crops such as vegetables that are not in the model to increase. We have also ignored second-round impacts such as those that might occur if employees request wage increases to compensate for higher food costs. Because of all of these omissions, the food price impact results should be considered a lower bound.

A second caveat concerns the acreage changes that would come about if the equilibrium price of corn rises to \$4.43 per bushel. We have assumed that yields for each U.S. producing region remain fixed at their baseline levels despite significantly greater corn acreage. One would think that increased corn plantings would begin to cause corn yields to decline because the additional corn acreage would not be planted as much in rotation with soybeans and it would be planted on increasingly marginal (lower-yielding) land outside of the Corn Belt. A decline in corn yields would decrease the supply elasticity of corn production with respect to price so that corn acreage would be smaller and other crop acreage would be greater than that reported. Total ethanol production from corn would also be proportionately less than our results indicate. High corn prices, however, are likely to counter this yield decline, as farmers would find it profitable to manage their crops more intensely, and seed companies would find it profitable to invest greater amounts in yield-increasing technologies. Whether the yield-decreasing effects of less crop rotation and less-productive land are greater than the yield-increasing effects of high prices cannot be known with certainty.

The last caveat has to do with ethanol trade policy. The no-bottleneck scenario assumes that the U.S. ethanol tariff structure remains in place. If the tariffs were removed (\$0.54 specific and 2.5% ad valorem), blenders would arbitrate between foreign and domestic sources of ethanol. Margins of U.S. ethanol plants would be affected negatively and their expansion would be more limited than reported, as they would receive the world ethanol price adjusted for transportation. Crop price increases would be moderate and the impacts on food prices would be smaller than those reported in Table 1. The world price of sugar would rise as sugar-cane ethanol production

would expand but with little consequence for the U.S. sugar price. The latter is not determined by the world sugar market but rather by domestic market conditions and policy.

Impact of a Short Crop

A major concern of livestock feeders is that they will not be able to compete with ethanol producers in a short-crop year caused by, for example, a widespread drought in the Corn Belt. With a large ethanol industry competing with livestock producers for corn, there is no doubt that corn prices would increase significantly in a short-crop year. Economic theory and historical events in 1995 suggest that corn prices would rise until operating margins of ethanol plants turn negative, at which point plants would begin to shut down, thereby increasing the supply of corn available to livestock feeders. The shut-down price can be inferred from Figures 5 and 6. If the short-crop occurred in 2010, then prices would have to increase by about \$0.65 per bushel to induce ethanol plants to shut down.

However, what if ethanol plants were operating under a mandate? In this case, any required adjustment in demand would occur outside the ethanol industry, which would continue to operate, covering the increased cost of corn by passing on higher ethanol prices to blenders. To see how the livestock industry would be affected by an ethanol mandate combined with a short crop, U.S. regional yields of corn, soybeans, and wheat in 2012 were changed from their trend levels by the same percentages that yields were observed to have changed from trend levels in 1988. The year 1988 was chosen because that was the most recent year of major drought in the U.S. Corn Belt. Figure 19 shows the yields that were assumed in the short-crop scenario. U.S. corn yields fall by about 25% in 2012. Soybean yields fall by about 18%, and wheat yields fall by 11%.

The ethanol mandate for 2012 is assumed to be 14.715 billion gallons. As shown in Figures 20 and 21, the short crop causes corn and soybean prices to spike in the 2012 marketing year. Corn prices rise 42% above baseline levels. Soybean prices rise by 22%. As shown in Figure 22, corn exports and stock levels both decrease by more than 60% in response to a short crop. The large reduction in exports results from ethanol producers and domestic livestock producers winning the competition with foreign buyers for U.S. corn. Corn exports from South America, China, and other countries increase to fill part of the decline in U.S. corn exports. The amount of corn fed by the U.S. livestock industry declines by 15% (845 million bushels). Part of this reduction is accounted for by a drop in production. Part is accounted for by a 50% increase (118 million bushels) in the amount of wheat that is fed.

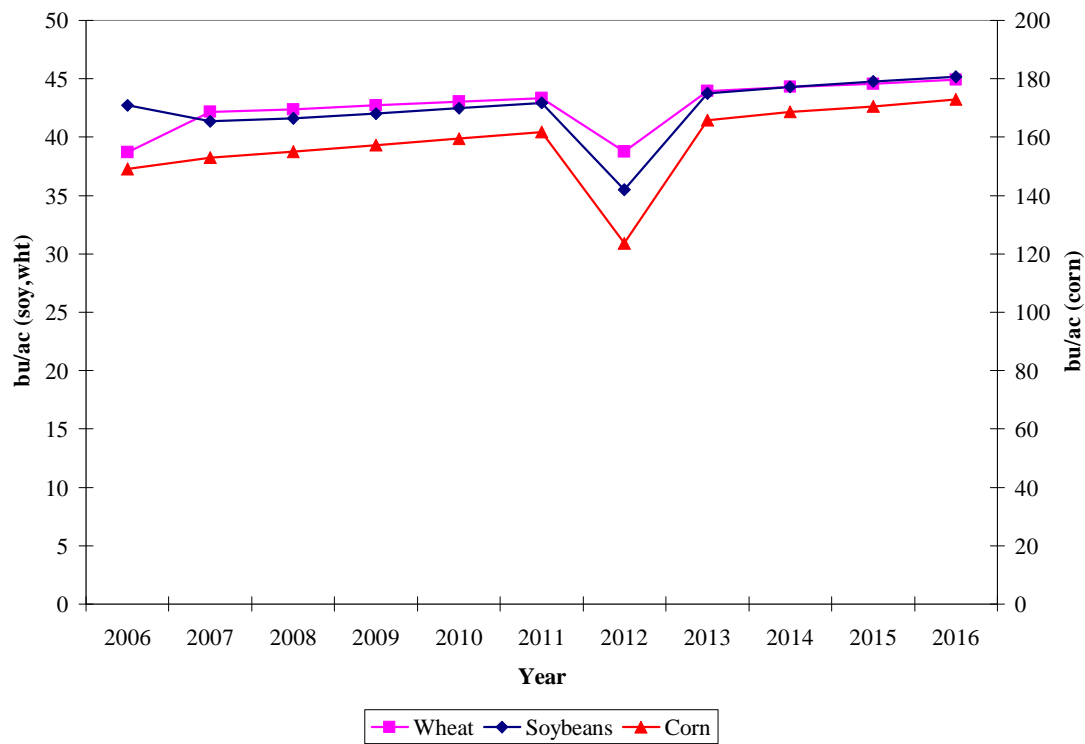


FIGURE 19. Yields in the short-crop scenario

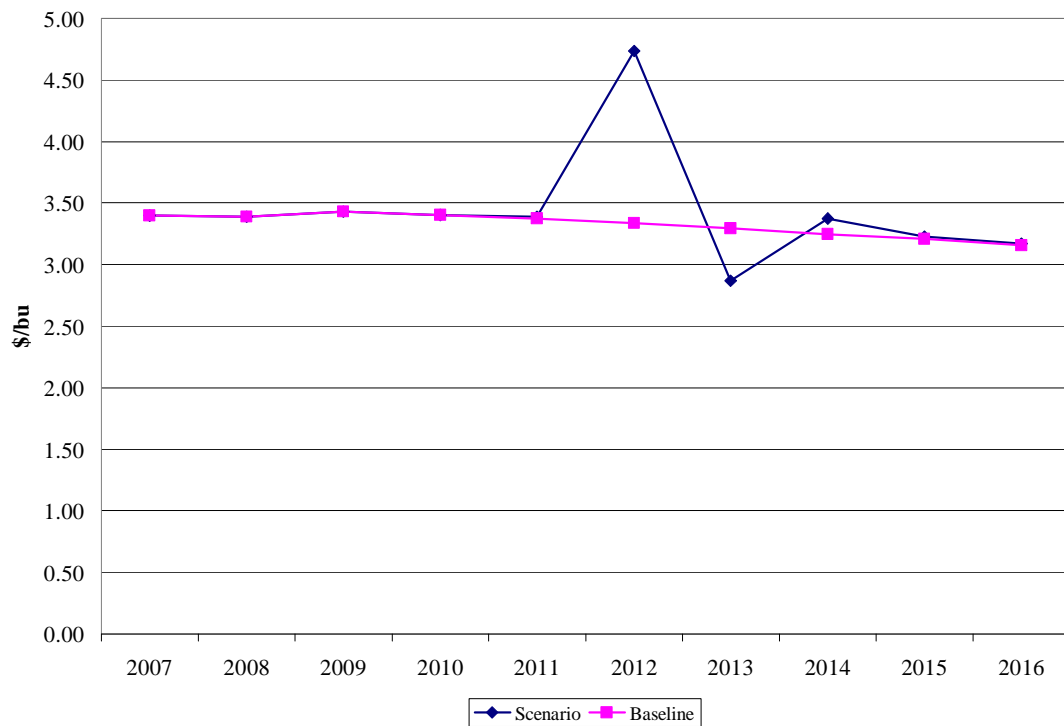


FIGURE 20. Corn prices in the short-crop scenario



FIGURE 21. Soybean prices in the short-crop scenario

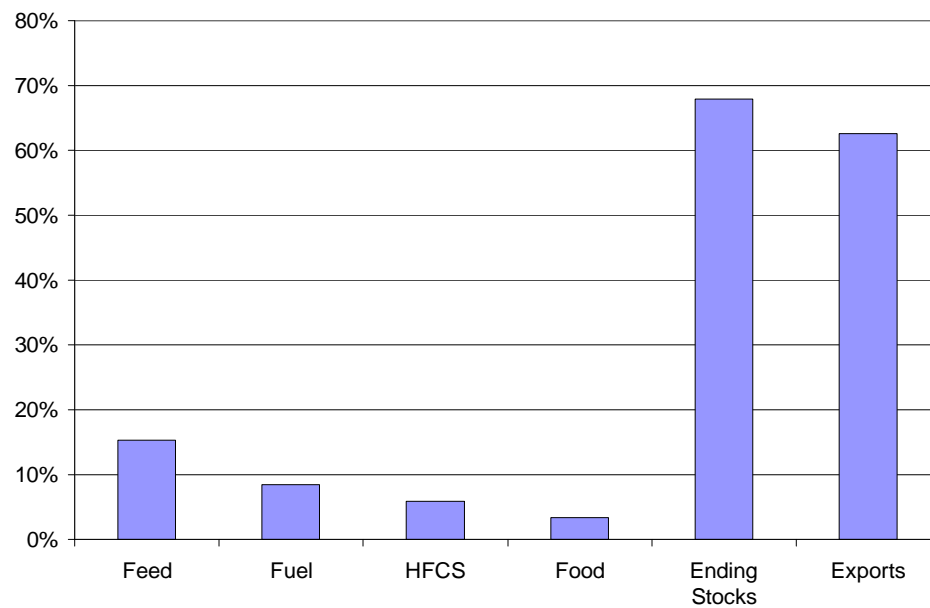


FIGURE 22. Reduction in 2012 corn use in the short-crop scenario

Ethanol trade increases moderately as the imported ethanol price inclusive of the tariff and transportation cost remains higher than the U.S. price. Under free ethanol trade, ethanol imports could play a bigger role in attenuating the negative impact of short crops under an ethanol mandate as blenders could source the ethanol more cheaply abroad.

Figure 23 shows the adjustment in production levels in calendar year 2013 due to higher feed costs. Broiler production decreases the most, at about 2.5%, with milk production adjusting the least, at about 0.5%. The amount of adjustment differs across these livestock products because of differences in feed rations, reliance on exports, and on the degree of competition each product faces. Figure 24 shows how the change in production and higher world feed costs will affect U.S. retail prices. Egg prices are projected to increase the most, at about 5%, followed by the other products, at about 3%. Prices and production levels are not affected by a greater amount in this scenario because livestock producers are assumed to view the production shock as being temporary. Thus, they do not adjust herd size as much as they would adjust to a permanent shock in feed prices.

Impacts on Exports

To highlight the impact that ethanol could have on exports, Table 2 presents projected U.S. exports of grains and meat under the baseline and the high oil, no E-85 bottleneck scenario for years 2007 to 2010 and in the long-run equilibrium. As shown, corn, soybean, and wheat exports would decline dramatically if high crude oil prices greatly stimulated U.S. ethanol production. In addition, exports of pork, broilers, and turkeys would decline, but by a smaller percentage than crop exports would decline. The reason for this difference is that world demand for U.S. meat is largely unaffected by higher feed-grain prices because the rest of the world's livestock producers also face higher feed prices. Total world meat consumption declines because of higher prices, but U.S. producers still would find it profitable to supply world markets. Beef exports are projected to increase because the price of beef relative to other meats declines.

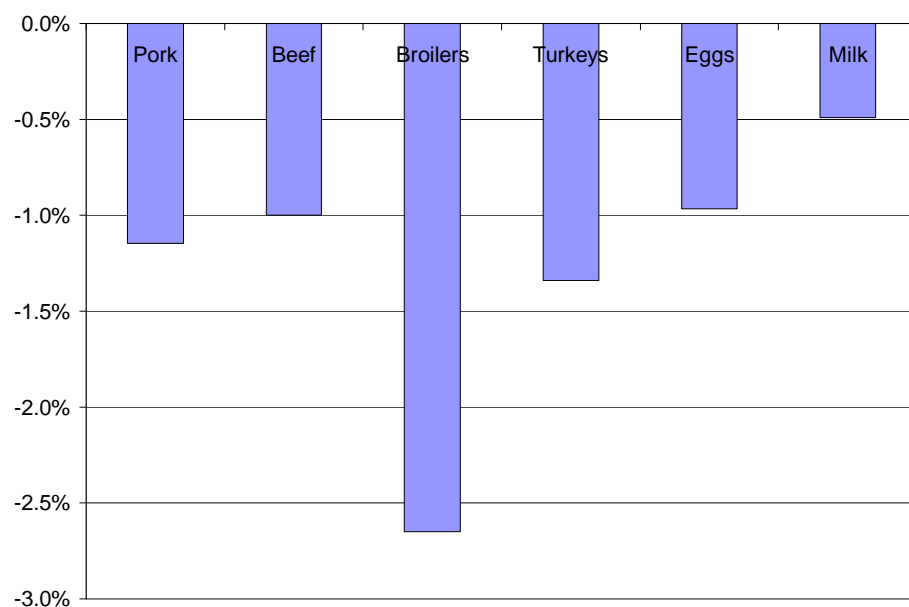


FIGURE 23. Change in 2013 livestock production in the short-crop scenario

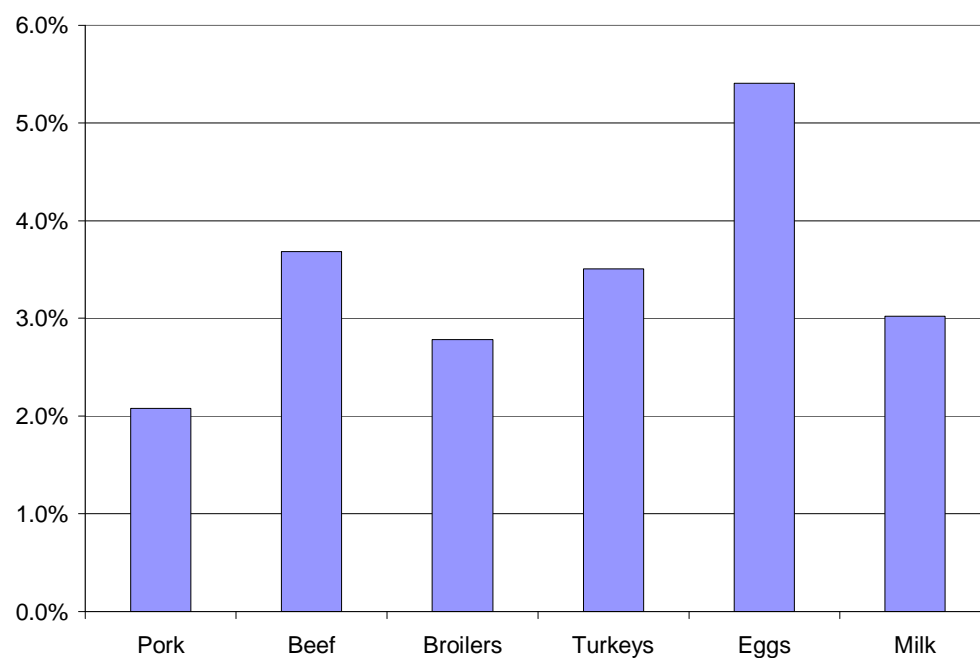


FIGURE 24. Change in 2013 retail prices in the short-crop scenario

TABLE 2. Impacts on exports from high-oil scenario

	2007	2008	2009	Long-Run
Corn (million bu)				
Baseline	1,664	1,509	1,527	2,451
Scenario	1,653	1,454	1,357	911
% Diff.	-0%	-4%	-11%	-63%
Soybeans (million bu)				
Baseline	1,096	999	966	880
Scenario	1,091	990	938	594
% Diff.	-0%	-1%	-3%	-33%
Wheat (million bu)				
Baseline	905	896	897	1,037
Scenario	784	576	525	483
% Diff.	-13%	-36%	-41%	-53%
Pork (million lbs)				
Baseline	3,161	3,283	3,378	4,139
Scenario	3,161	3,285	3,381	3,280
% Diff.	0%	0%	0%	-21%
Beef (million lbs)				
Baseline	1,414	1,709	2,020	2,249
Scenario	1,415	1,716	2,035	2,439
% Diff.	0%	0%	1%	8%
Broilers (million lbs)				
Baseline	5,410	5,503	5,634	6,820
Scenario	5,416	5,527	5,667	5,763
% Diff.	0%	0%	1%	-15%
Turkey (million lbs)				
Baseline	585	595	609	738
Scenario	585	597	612	690
% Diff.	0%	0%	1%	-6%

State-Level Corn and Distillers Grains Projections

To see how the expansion of the ethanol industry is changing the flow of corn and DG across the United States, we now compare baseline and scenario state-level corn utilization rates. State-level domestic surplus corn and DG is the amount of product remaining in a state after accounting for ethanol, livestock feed, and other processing in a state. To do that for corn, we estimated corn usage for ethanol and livestock feed by state and combined those estimates with

estimates of state corn processing for non-ethanol purposes and corn production numbers from USDA. Based on the figures by state of corn used for ethanol, we computed the DG production by state and estimated DG usage in livestock feed. Domestic surplus corn and DG are corn and DG that are either maintained in stocks or available for export to other states or countries. We estimated domestic surplus corn for 2004 and projections in 2010 for corn and DG under the two scenarios.

Figure 25 shows the state-level corn situation in 2004. The 2004 crop year was a record breaker for corn, with U.S. corn production of 11.8 billion bushels. Domestic livestock consumed over 6 billion bushels of that crop. Ethanol captured over 1 billion bushels, and other corn processing took over 1 billion bushels as well. That left roughly 3 billion bushels of domestic surplus corn for exports and stocks. As Figure 25 shows, the surplus corn came from the upper Midwest. Sixteen states produced more corn than they used. Illinois had the most surplus corn, at 1.4 billion bushels, but Iowa, Minnesota, Indiana, and Nebraska all had over 500 million bushels of surplus corn each. The major corn-importing states were California, Texas, North Carolina, Georgia, and Alabama.

The projection models in this analysis contain national-level projections for corn production, corn usage by category, DG production, and DG usage. For the 2010 state-level projections, we distribute the national numbers across the states based on 2006 livestock numbers, current corn processing capacity, and current and planned ethanol production capacity. Under the higher crude oil price scenario, we assume that the increase in ethanol production will be centered in areas with surplus corn.

For the 2010 baseline scenario, U.S. corn production increases to 13.8 billion bushels. Given our assumptions, nationwide there would be a total of just over 1.6 billion bushels of domestic surplus corn available for export to other countries or to place in stocks. The projected corn acreage increase is not enough to completely offset the combination of a return to trend yields and the expansion of ethanol. As shown in Figure 26, Illinois holds firm at 1.4 billion bushels of surplus corn, but other Midwestern states experience sizable drops in surplus corn. Iowa falls from second to fourth in surplus corn, as the state will have only 379 million bushels left after accounting for in-state uses. Nebraska and Indiana also have significant drops in surplus corn.

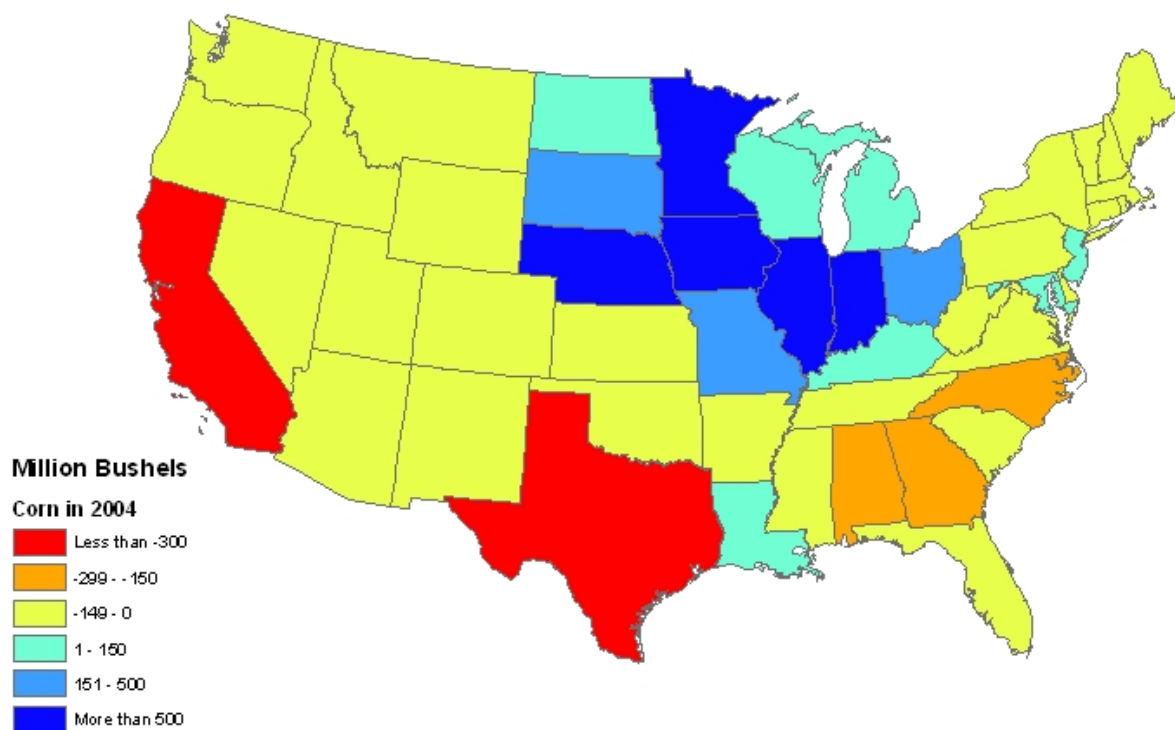


FIGURE 25. Domestic surplus corn in 2004

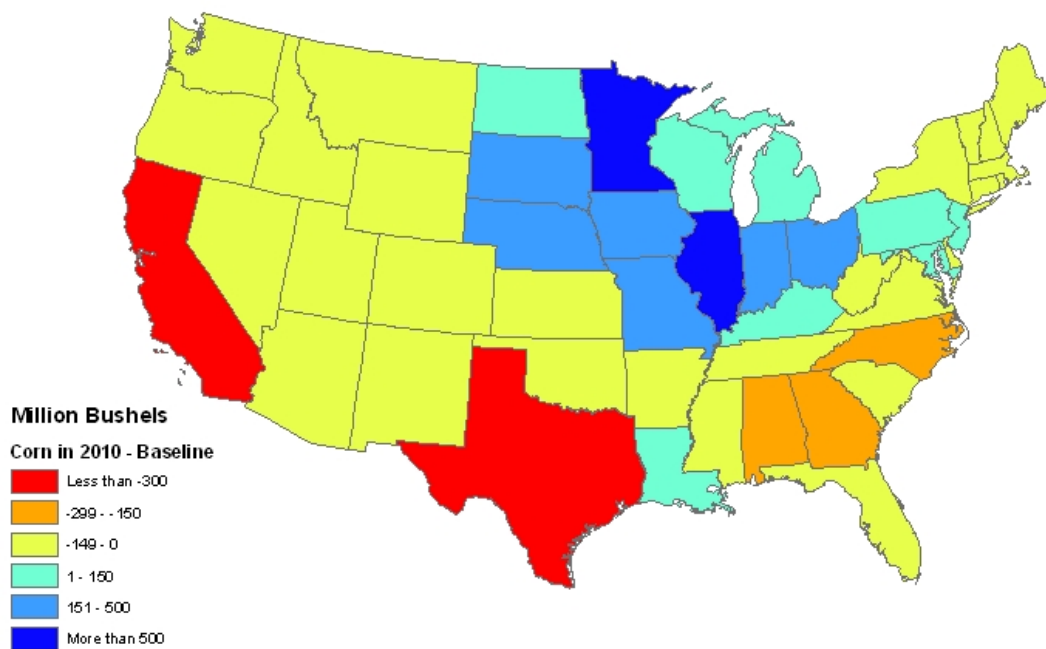


FIGURE 26. Domestic surplus corn in 2010—baseline

Figure 27 shows the projected state-level DG situation. Fifteen states are projected to produce more DG than livestock producers in those states will use. Most of those states are in the upper Midwest, but there are exceptions. Iowa and Illinois will produce over 3 million tons of surplus DG each, but most of that surplus will be utilized by livestock producers in Kansas and Texas. Given the ability to incorporate more DG in feed rations of cattle over those of hogs and poultry, projected DG usage is stacked toward cattle-producing states, such as Texas, Kansas, and Nebraska.

Figures 28 and 29 show the maps for the higher crude oil price scenario. For that scenario in 2010, U.S. corn production increases to 14.3 billion bushels. But the higher crude oil price translates into stronger growth in the ethanol industry. The projected growth in the ethanol industry exceeds the growth in corn production; thus, domestic surplus corn falls to just over 1.2 billion bushels. Based on the assumption that additional ethanol plants will locate in areas with surplus corn, Illinois attracts most of the additional ethanol plants in the scenario but maintains its position as the top producer of surplus corn. Given the projected expansion of ethanol in this scenario, additional ethanol production is also projected for Minnesota, Indiana, Iowa, Nebraska, Missouri, and Ohio. The boost in ethanol production also implies an increase in DG production. Minnesota joins Illinois and Iowa as large-scale producers of surplus DG. Iowa produces over 7.5 million tons of surplus DG, after accounting for projected livestock feeding in the state. The increase in DG production nationwide exceeds the demand by domestic livestock producers and provides sizable quantities for export.

Figure 30 provides a more detailed look at the corn situation in the upper Midwest under the two scenarios. Under the baseline analysis, only Illinois and Missouri are projected to have more surplus corn than in 2004. Iowa has the largest decline in surplus corn, with Nebraska also having a sizable drop. Under the higher crude oil price scenario, all of the states in the upper Midwest are projected to have less surplus corn.

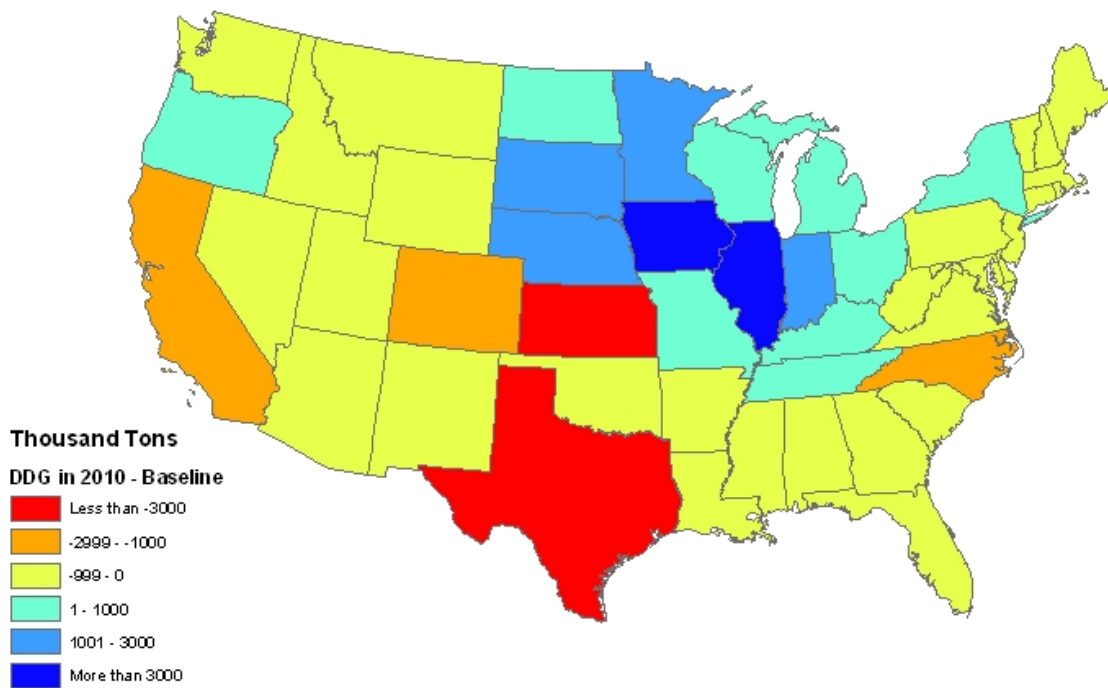


FIGURE 27. Domestic surplus distillers grains in 2010—baseline

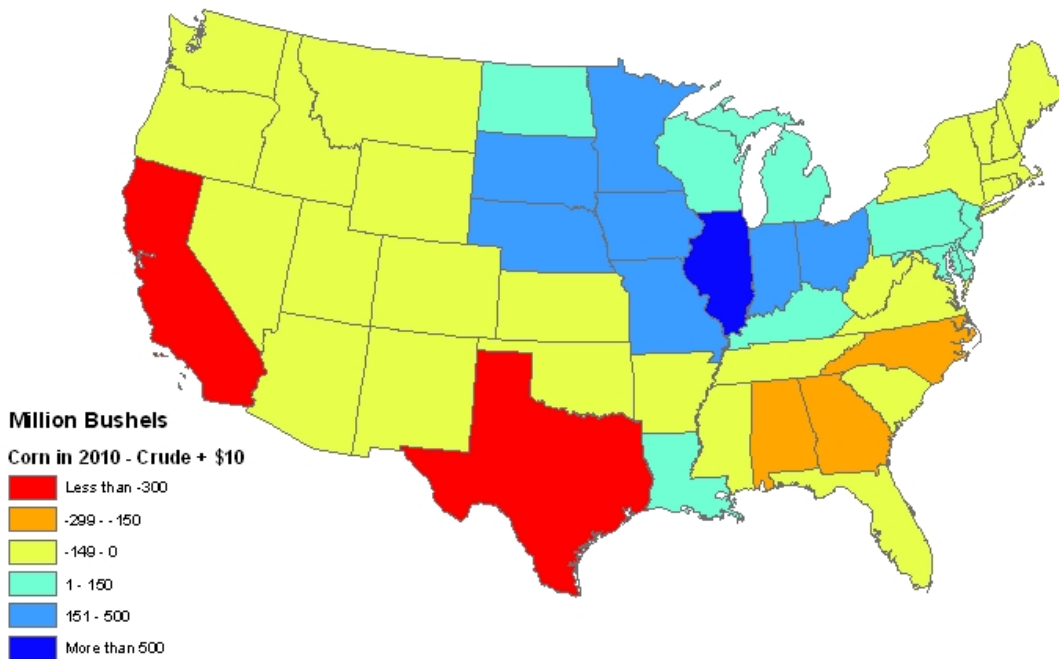


FIGURE 28. Domestic surplus corn in 2010—oil plus \$10

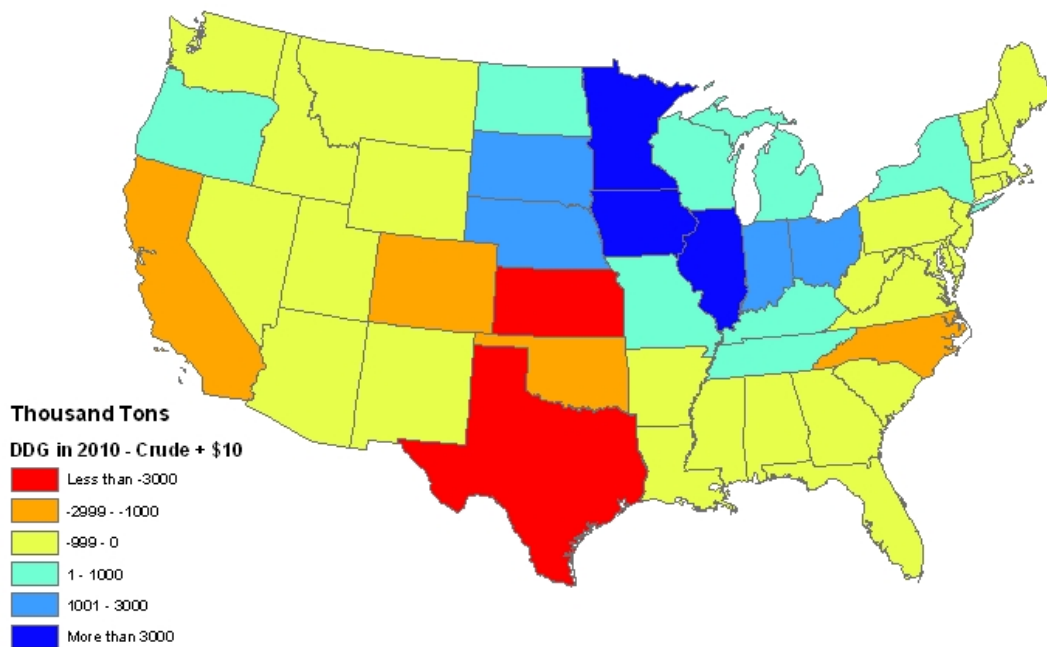


FIGURE 29. Domestic surplus distillers grains in 2010—oil plus \$10

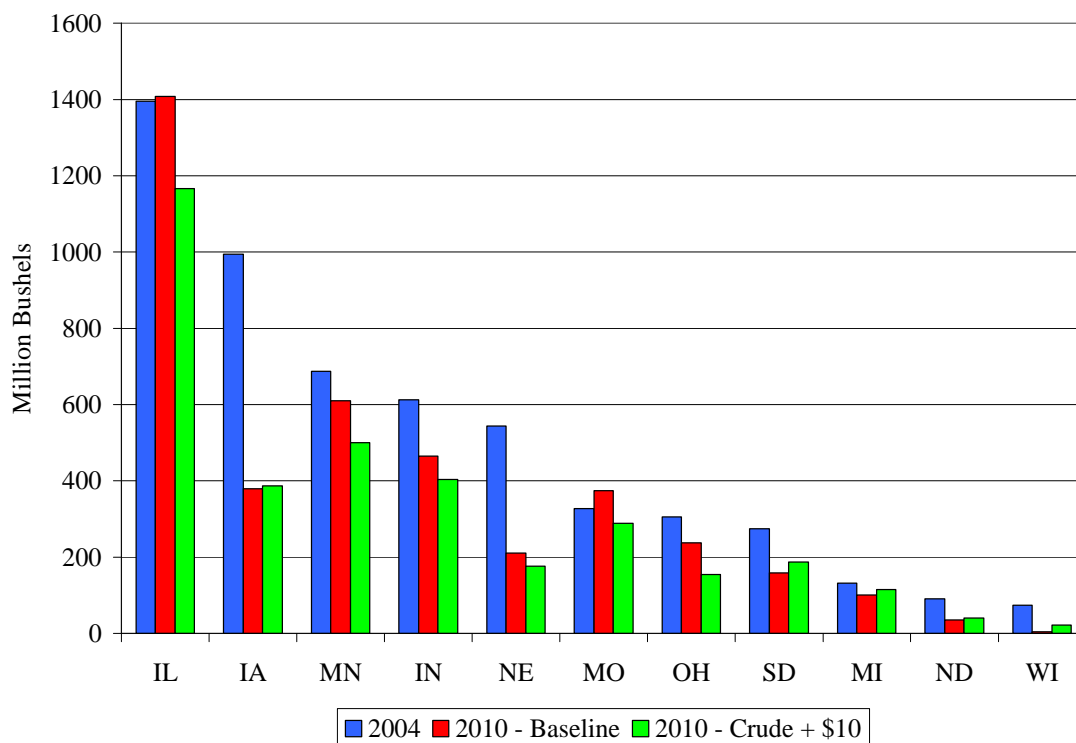


FIGURE 30. Domestic surplus corn in the Midwest

The Lack of Cellulosic Ethanol in the Scenarios

The tools we have used assume that individuals are self-interested and that they will not invest in a facility or business venture unless they have an expectation of making a positive return. We looked at two forms of cellulosic ethanol that would rely on feedstock from the Corn Belt and discovered that neither one would be economically justifiable, even given the higher crude oil and corn prices in our oil-plus-\$10 scenario. We do not analyze the viability of cellulosic feedstocks from other regions, such as wood chips from the Southeast.

Economic Feasibility of Stover-Based Ethanol

The best available information on the production costs for corn-stover-based ethanol comes from the June 2002 technical report by Aden et al. of the National Renewable Energy Laboratory (NREL). This provides a very detailed model of a cellulosic ethanol facility and provides detailed cost estimates. We used the NREL estimates for a plant that uses 2,000 tons per day and produces 51 million gallons per year, as suggested by the report. This plant has a 50-mile-radius draw area for stover. We assumed that the plant offers a plant-gate price that attracts stover from the edge of this draw area.

While we agree with much of the research in this report, we disagree with one key assumption. The report details all of the costs associated with the baling and transportation of corn stover, and these calculations sum to \$62 per dry metric ton. This is about \$31 for a 1,265 pound bale of 15% moisture stover. The authors then arbitrarily assume that this cost will be reduced to \$33 per dry metric ton in the future through “improved collection.” We are of the opinion that farmers and agricultural equipment manufacturers have already squeezed costs from this system, and we do not expect these costs to fall dramatically. In fact, because some of the costs are themselves transportation related, they would be higher under a higher oil price scenario.

We compiled our own stover collection costs from Iowa State University Extension (2006) for 1,265 pound bales as follows: baling, \$10.10; staging, \$2.25; and hauling, \$15.00 (\$0.30 per mile for 50 miles). We excluded chopping charges of \$8 per acre or \$2 per bale because we could not be sure in what form the plant would ideally like to receive these bales. In addition, we used the NREL estimates of the required premium to farmers of \$5.50/bale and a lost fertilizer value of \$4.00/bale. The total cost per delivered dry ton is \$73.70. With

an assumed conversion of 70 gallons per ton, the raw material cost is \$1.05 per gallon.

We then used the capital cost of \$197.4 million from the NREL report amortized over 10 year at 10% interest with annual payments of \$31.3 million to get a capital charge per gallon of \$0.61. We used the variable costs of 36¢ per gallon from Tables 30 and 32 of the NREL report.

Table 3 compares these costs to those for a corn-based ethanol plant for a year in which corn is worth \$4.50 per bushel delivered to the plant. We assumed that the corn-based ethanol plant could sell DG at \$150 per ton and used the assumptions from the Elobeid et al. report for the fixed and variable costs for this corn-based ethanol plant.

By its authors' own admission, the NREL report is based on optimistic assumptions about the process. In particular, the variable costs of running the plant are low because the NREL report assumes dramatic reductions from current levels in the costs of the catalysts and enzymes, and it assumes much lower labor costs than were used in the Elobeid et al. report. For example, the NREL report assumes that secretaries and yard employees would earn \$20,000 per year on average including benefits. This is probably low given current labor market conditions in the counties where these plants are being built.

TABLE 3. Cost comparison: corn stover versus corn for ethanol

	Corn Stover	Corn
	<i>(\$ per gallon of ethanol)</i>	
Raw material costs	1.05	1.15
Capital costs	0.61	0.24
Operating costs	0.36	0.52
Total	2.02	1.91

Even with this set of optimistic assumptions, our analysis shows that it does not pay to produce ethanol with corn stover when corn is \$4.50. In fact, it takes a corn price of \$4.80 to make the investor indifferent between a cellulosic ethanol plant and a corn-based ethanol plant. This \$4.80 breakeven price would increase if we added costs associated with chopping straw or wrapping bales. It would fall if the investors were willing to accept a lower rate of return or if a longer plant life were projected.

Economic Feasibility of Switchgrass-Based Ethanol

In addition to some of the same disadvantages associated with baling and moving corn stover, switchgrass in the Corn Belt must also compete against corn and soybeans for land. Corn stover does not have this hurdle because it is a by-product of corn production.

Farmers will not be willing to plant switchgrass unless it offers a net return comparable to that of corn. Babcock et al. (2007) calculated the price at which farmers would consider changing to switchgrass as \$110 per ton of switchgrass from land with a yield of four tons per acre and \$82 per ton for land with a yield of six tons per acre. The maximum that ethanol plants can bid for these same tons is about \$37 per ton in years when ethanol is selling for \$1.75 per gallon. Under these conditions, switchgrass simply cannot offer farmers a market incentive that offsets the advantages of growing corn.

A key and possibly counterintuitive insight is that there is no ethanol price that makes it worthwhile to grow switchgrass because any ethanol price that allows ethanol plants to pay more for switchgrass also allows them to pay more for corn. So long as farms are responding to net returns in a rational manner and so long as ethanol plants are paying their breakeven price for raw material, farmers will plant corn as an energy crop. Switchgrass in the Corn Belt will make economic sense only if it receives an additional subsidy that is not provided for corn-based ethanol.

Biodiesel

The same logic that works against switchgrass also works against biodiesel. The main crop for U.S. production of biodiesel is soybeans. Soybeans produce fewer bushels per acre and less energy value per bushel than corn, so as long as markets are working, and in equilibrium, producers targeting energy crops would choose corn over soybeans.

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