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Economic Parameters for Corn Ethanol and Biodiesel Production

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This article presents current investment and operating costs of ethanol and biodiesel plants for alternative prices of feedstock. The price of these two fuels is estimated for alternative prices of crude oil with the existing renewable fuels policy. The excise tax credit, currently $0.51 per gallon of ethanol and $1.00 per gallon of biodiesel, is a major contributor to the fuel price and profitability of these industries. The analysis demonstrates how the crude oil price, feedstock price, and excise tax credits interact to impact profitability of these industries.

Key Words: biodiesel, biofuels, ethanol, renewable energy

JEL Classifications: Q13, Q18, Q28, Q42

Ethanol and biodiesel production in the United States has increased rapidly over the past two years. Ethanol production increased from 3.4 billion gallons in 2004 to 3.9 billion gallons in 2005, an increase of 500 million gallons. Production in 2006 was about 4.9 billion gallons, 1 billion gallons more than in 2005 (Renewable Fuels Association). Even greater rates of increase are projected for the next two years. In a recent industry workshop, a representative of one of the major ethanol plant builders estimated that production capacity in the United States will increase from 5.4 billion gallons at the beginning of 2007 to 8.7 billion gallons by the beginning of 2008, and to at least 11 billion gallons by the beginning of 2009 (Krissek). The increases of the past two years are unprecedented; now many in the industry are expecting increases in production capacity of 3.3 and 2.3 billion gallons during 2007 and 2008, respectively. If these rates of increase are realized, the industry should produce about 7, 9.35, and over 11 billion gallons of ethanol from grain in 2007, 2008, and 2009, respectively. The data on plants under construction seem to verify the likelihood of these large increases (Renewable Fuels Association).

The biodiesel industry is at an earlier stage of development than ethanol from grain. However, biodiesel also increased production very rapidly over the past two years, from 25 million gallons in 2004 to 75 million gallons in 2005, and to 250 million gallons in 2006 (National Biodiesel Board). The industry had 87 plants with 582 million gallons of capacity in November 2006, with a number of additional plants and plant expansions under construction. The National Biodiesel Board estimates these construction projects will be completed by the close of 2007, bringing total industry capacity to 1.4 billion gallons per year. However, much of this capacity is dedicated to the production of other products including soap, shampoo, olestra cooking oil, and other products, making it difficult to determine how much capacity is dedicated to fuel production.

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The rapid rates of growth have resulted from favorable market conditions for the production of grain—ethanol and biodiesel. Relatively high petroleum prices, the phase-out of methyl tertiary-butyl ether (MTBE), passage of the excise tax credit for biodiesel, and relatively constant production costs contributed to the favorable economic climate for these two biofuels during the past two years.

Many are questioning the continued profitability of the ethanol and biodiesel industries over the next several years, saying the rapid rate of growth of the industries will drive up the cost of the feedstocks. While many factors will impact the profitability of these industries, three are likely to be of major importance: the price of petroleum, the price of the feedstocks (corn, vegetable oils, used cooking grease, and animal fats), and policy. This article explores the interaction of these three variables on the profitability of ethanol and biodiesel production. The first section summarizes the federal policies that are currently in place. The second section discusses the profitability of grain ethanol production under alternative corn and petroleum price conditions. The final section evaluates the profitability of biodiesel production under alternative fuel and feedstock prices.

The Current Federal Policy Environment

The Energy Policy Act of 2005 established a renewable fuels standard (RFS) that requires the petroleum industry to blend a minimum amount of renewable fuels with petroleum fuels each year. Those amounts are 4 billion gallons during 2006, increasing 700 million gallons per year to 6.8 billion gallons in 2010, to 7.4 billion gallons in 2011 and 7.5 billion gallons in 2012. As noted above, the U.S. ethanol industry marketed about 4.9 billion gallons during 2006 and expects to sell much more ethanol each year through 2010 than the amount required by the RFS. Congress is currently considering adopting a revised RFS with requirements that are closer to the expected production levels of ethanol and biodiesel. If the proposed legislation becomes law, it may have a greater impact on ethanol demand than the RFS currently in force.

The RFS replaced the reformulated gasoline oxygenate requirement and gave refiners more flexibility in formulating gasoline. Even though the petroleum companies requested the additional flexibility, they continue to use ethanol as the oxygenate in producing reformulated gasoline. The 2005 act neither banned the use of MTBE nor created liability protection for companies blending MTBE. Without liability protection, however, refiners decided to replace MTBE with ethanol effective May 2006, greatly increasing the demand for ethanol.

The federal winter oxygenate program continues, which requires certain geographic areas to include 2% oxygen (by weight) in winter-month gasoline to combat carbon monoxide from automobile exhaust. This requirement was not repealed with the reformulated gasoline standard. Areas still covered by this program include parts of Texas, California, Nevada, and Montana. Many areas formerly required to participate have achieved the required air quality standards and are no longer in the program.

Perhaps the two most important programs for a discussion of ethanol profitability are the Volumetric Ethanol Excise Tax Credit (VEETC) and the small ethanol producer tax credit. VEETC provides a $0.51 excise tax credit per gallon of ethanol blended. The credit goes to the blender and is paid in proportion to the amount of ethanol used in the blend. The program is scheduled to terminate at the end of 2010, unless it is extended. The small producer tax credit provides an income tax credit for the ethanol plant of $0.10 per gallon on the first 15 million gallons produced per year, a maximum of $1.5 million annually per plant. It is available for plants producing 60 million gallons or less per year, and the tax credit can be passed through to owners of a cooperative plant. This program also is in effect through 2010 (Renewable Fuels Association).

Biodiesel also has both a volumetric excise tax credit and a small producer tax credit program. The American Job Creation Act of 2004 provided an excise tax credit of $1.00 per gallon of agri-biodiesel made from (virgin) vegetable oils and animal fats. Biodiesel made from used oils, such as yellow and brown grease, receive an excise tax credit of $0.50 per gallon. Biodiesel plants producing 60 million gallons per year or less are also eligible for the small producer tax credit of up to $1.5 million per year. Both the excise tax credit and the small producer income tax credit are in effect through December 31, 2008, for biodiesel (National Biodiesel Board).

Countries eligible to export ethanol to the United States through the Caribbean Initiative can export to the United States duty free. The maximum amount that can be imported through this provision is limited to 7% of the previous year's domestic use. Imports from other countries are required to pay an import tariff of $0.54 per gallon. The United States does not appear to have any tariffs in place that limit the importation of vegetable oils for biodiesel production.

Given this set of policies, let's consider the cost of producing ethanol and biodiesel. The analysis is for "turn-key" ethanol and biodiesel plants, the most common type that are built and operated in the upper Midwest.

Grain Ethanol Production Costs

The standard ethanol plant is a natural-gas–fired plant that processes corn and produces denatured ethanol, dried distillers' grains with solubles (DDGS), and CO_2. Most Midwest plants sell two products, denatured ethanol and DDGS, but do not have a market for the CO_2 that is vented. The standard plant has a rail siding to handle a unit train and 10 days of storage capacity for corn, ethanol, and DDGS. The initial investment includes funds to pay for the legal fees associated with the project, purchase of the building site, obtaining the required permits, developing the water supply, the dirt work, building the plant, starting the plant, and the initial operating capital (usually 10% of the total).

Investment Costs

Although this general description of a standard plant has not changed much over the past two years, the investment cost per gallon has increased, the size of the "small plants" being built has increased, and the economies of scale are greater than they were two years ago. In the 2003 through early 2005 period, we estimated the investment costs to be $1.25 per gallon of annual capacity of a plant producing 48 million gallons per year and $0.97 per gallon of annual capacity for a plant producing 120 million gallons per year (Tiffany and Eidman; Nicola). By the end of 2006 these costs had increased substantially. A generic grain ethanol plant producing 60 million gallons per year has investment costs of $1.875 per gallon of output, while a plant producing 120 million gallons per year has investment costs of $1.50 per gallon of annual capacity. Thus, the current initial investment in a 60 million gallon plant is about $112.5 million, and the investment in building a 120 million gallon plant is $180 million. The major reasons for the increase in the initial investment are the higher costs of stainless steel, copper, and concrete; and the additional costs construction firms incur when they must manage a larger number of projects in a given amount of time.

Cost per Gallon

The cost of ethanol production for alternative conditions was estimated with the ethanol success spreadsheet (Tiffany and Eidman).The analysis assumes 2.75 gallons of anhydrous (2.81 gallons of denatured) ethanol and 18 pounds of DDGS are produced per bushel of corn. When corn is $2.00 per bushel, the price of DDGS is assumed to be equal to the price of corn ($0.0357/lb. or $71.43 per ton). The analysis builds in a 12% rate of return to equity capital, which I consider a normal rate of return.

The net cost per gallon when the price of corn is $2.00 per bushel is $1.40 for the smaller plant and $1.31 for the larger plant (Table 1). The larger plant has lower capital and labor and management costs per gallon, $0.07 and $0.0182, respectively. These economies are greater than the $0.035 Nicola found in 2005 because of the higher capital cost. The larger

Table 1. Estimated Ethanol Production Costs for New Construction[a]

Corn Price ($/Bushel)	60 Million Gallons per Year ($/Gallon)	120 Million Gallons per Year ($/Gallon)
2.00	1.40	1.31
3.00	1.66	1.57
4.00	1.92	1.83
5.00	2.18	2.09
6.00	2.44	2.35

[a] The costs include a return to equity capital of 12% and a cost of natural gas of $10 per million Btu. Each $1 change in the cost of natural gas changes the cost per gallon $0.034 in the same direction.

plant may also have lower marketing, transportation, and risk management costs per gallon, but no effort was made to quantify those differences. It should be noted that the small producer tax credit of $1.5 million could offset 2.5 of the 9 cents, reducing the difference to 6.5 cents per gallon. Even with this credit, the remaining economies suggest the larger plants have a major competitive advantage in producing ethanol for what is a commodity market.

The price of corn has a major impact on the cost of producing ethanol. The net cost of ethanol increases $0.356 as the cost of corn increases $1.00 per bushel if the price of DDGS remains $71.43 per ton. However, the net increase in the cost per gallon is only $0.24 if the price of DDGS increases in proportion to the price of corn. The markets suggest the price of DDGS follows the corn price, but not in proportion. Thus, the net cost per gallon for alternative corn prices in Table 1 assumes the price of DDGS increase at approximately 92% of the increase in the corn price. This results in a net increase of $0.26 per gallon of ethanol for each $1 per bushel increase in the price of corn.

The cost per gallon is sensitive to many other factors. One of the more important is the price of the boiler fuel. This analysis assumes the plant uses 34,000 Btu per gallon of ethanol produced, and the impact of a $1 change in the price of natural gas is $0.034 per gallon of ethanol. Thus, the cost of ethanol with natural gas at $8 per million Btu instead of $10 is $0.068 less per gallon than the costs shown in Table 1.

Ethanol Price

In addition to the cost of producing the ethanol, the profitability of an ethanol plant depends on the netback price it receives for the ethanol sold. The market price of ethanol tends to follow the price of gasoline, which depends on the price of petroleum, and the policies that mandate or subsidize the use of ethanol. The netback price a plant receives is the market price less the cost of transportation and marketing required to move the ethanol from the plant to the market. The netback price varies from plant to plant, but it is assumed to be $0.20 per gallon in this analysis.

The average relationship between the refiners acquisition cost of crude oil and the wholesale price of regular gasoline, estimated from national data (U.S. DOE 2007), is given by Equation (1) for the period January 2000 through 2006. This relationship accounts for much of the variation in gasoline prices ($R^2 = 0.95$). While the price of crude oil is the major factor influencing the wholesale price of gasoline, the price also fluctuates in response to seasonal driving patterns and product supply/demand imbalances. Unexpected increases in demand or interruptions in supply may temporarily reduce stocks and raise prices. Environmental programs that are unique to an area also may influence prices. This relationship indicates the monthly average price of gasoline with $60 per barrel crude oil can be expected to be $1.84, with

$$(1)\quad \underset{(0.1013)}{WP_G} = \underset{(0.0296)}{\$0.0370} + \underset{(0.0008)}{0.0300P_C},$$

where

WP_G = wholesale price of gasoline per gallon
P_C = price of crude oil in $ per barrel,

the price increasing (decreasing) $0.30 per gallon with each $10 increase (decrease) in the acquisition cost of crude oil (Table 2).

Table 2. Estimated Average Wholesale Regular Gasoline Price

Refiners Acquisition Cost ($/Barrel)	Wholesale Gasoline Price ($/Gallon)
40	1.24
50	1.54
60	1.84
70	2.14
80	2.44

The relationship between the price of ethanol and wholesale gasoline is illustrated in Figure 1. The ethanol price exceeded the wholesale price of gasoline by an average of $0.35 per gallon over the January 2002 through December 2004 period. After the passage of the Energy Policy Act in August 2005 and petroleum companies began bidding for enough ethanol to replace the MTBE being used, the premium for ethanol increased to much higher levels of $0.50 to $0.70 per gallon. These high premiums are expected to decline after the industry expands to about 6 billion gallons of output per year, the amount of ethanol DOE estimates is needed to replace the MTBE and provide the ethanol needed to supply other historic blending needs (USDOE 2006). Industry representatives suggest the premium will decline to $0.20 to 0.25 per gallon after ethanol supplies expand to fill the need. If that occurs and the marketing and transportation costs paid by the plant are $0.20 per gallon, then the netback price of ethanol will be about $0.05 above the wholesale price of gasoline, or about $1.89 per gallon when the price of crude oil is $60 per barrel. And the netback price of ethanol should increase (decrease) about $0.30 per gallon as the price of crude oil increases (decreases) $10 per barrel.

What Can Plants Afford to Pay for Corn?

Comparing the numbers in Tables 1 and 2 suggests that with $60 per barrel oil, 60 million gallon ethanol plants will earn normal profits when the cost of their corn is about $3.90 per bushel, while 120 million gallon plants earn normal profits at about $4.25 per bushel. These plants should earn a higher (lower) rate of return when corn prices are less

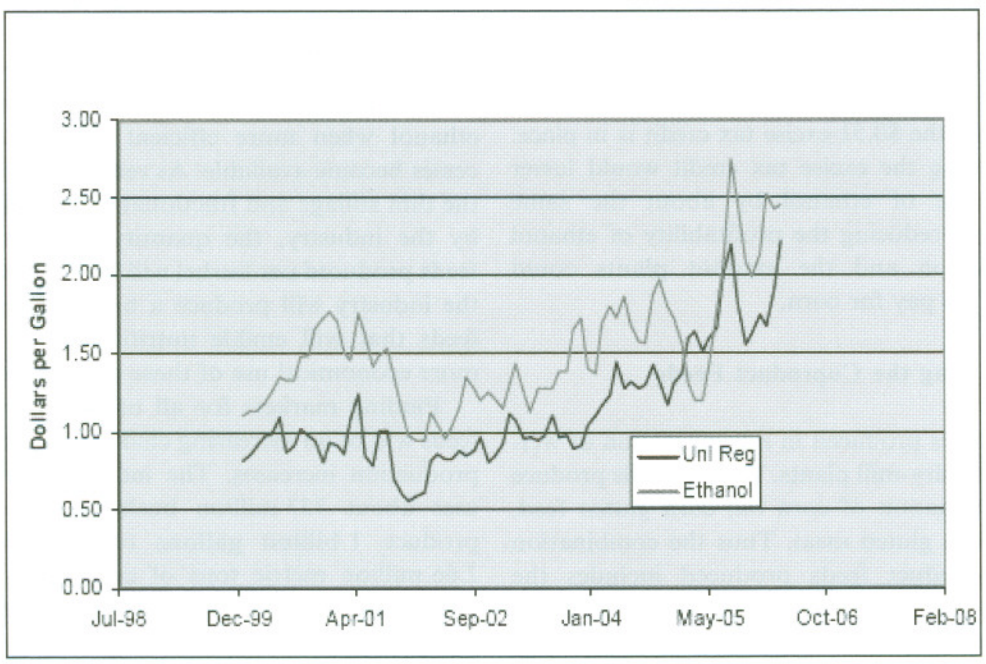

Figure 1. Omaha Rack Price for Ethanol and Regular Gasoline (Source: Nebraska Government Website)

Table 3. U.S. Coproduct Feed Usage Possibilities*

Species	Grain-Consuming Animal Units (Millions)	Maximum Rate of Inclusion in Diet	1,000 Metric Tons by Percentage Market Penetration		
			50%	75%	100%
Dairy	10.2	20%	1,887	2,831	3,774
Beef	24.8	40%	9,176	13,764	18,352
Pork	23.8	20%	4,348	6,521	8,695
Poultry	31.1	10%	2,877	4,315	5,754
Total			18,288	27,431	36,575

Source: Based on data presented by Geoff Cooper, and maximum inclusion rates from Distillers Grains Feeding Recommendations.

(more) than the above levels. Thus an expectation of corn prices around $4.00 per bushel should discourage continued investment in new facilities, unless those making the investment expect the price of oil to remain above $60 per barrel.

With a netback price of $1.89 per gallon, the price of corn at which existing plants would cease operations is much higher. Considering the costs the plant cannot avoid by shutting down suggests both plants would be willing to bid for corn up to $5.33 per bushel in the short run to continue operating. The plants would probably be losing money at a rapid rate at this price and would not continue to do so for very long.

It should be noted this price of ethanol assumes the $0.51 excise tax credit is in place. Removing the excise tax credit would lower the price of ethanol by about the same amount, reducing the profitability of ethanol production and the amount plants could afford to pay for corn.

Marketing the Coproduct Feeds

Ethanol is produced in a combination of wet-mill and dry-mill plants. The wet mills produce a combination of corn oil, corn gluten feed, and corn gluten meal. Thus the combination of coproduct feeds produced includes the above two feeds from wet mills, and wet distillers' grains and DDGS from dry mills. The production of these coproduct feeds has averaged about 16.4 pounds of dry matter per bushel of corn processed.

Some dry mills are beginning to use two new technologies that will broaden the array of coproduct feeds produced. One of these removes corn oil from the distillers' solubles after the fermentation is completed. This process removes up to 78% of the corn oil and captures it as a feedstock for use in producing biodiesel. This process removes most of the oil from DDGS, changing the composition of the feed and reducing the oil and energy content. The second technology is fractionation, which divides the kernel into the pericarp, the germ, and the endosperm. The endosperm is processed to make ethanol while the germ is used to make corn oil, a high-protein feed and a high-fiber feed. The pericarp is often used for fuel and may be converted to ethanol when more efficient cellulosic processes become available. As removing oil from the thin stillage and fractionation are adopted by the industry, the quantity of coproduct feeds produced per bushel will be reduced, and the industry will produce a broader array of feeds that will enable nutritionists to make more economical use of these coproducts.

Finding markets for all of the coproduct feeds will be an increasing challenge as ethanol production increases. The industry currently uses about 357 million bushels of corn to produce 1 billion gallons of ethanol and 2.66 million metric tons of coproduct feeds. Producing 10 billion gallons of ethanol would result in 26.6 million metric tons of coproduct feeds, almost enough to feed 75% of the livestock and poultry in the United States at the maximum recommended inclusion rates

(Table 3). It may be difficult to achieve such high adoption rates. What about exports? Exports increased to about 1.25 million metric tons in 2006. Of these 25% went to the European Union, 10% to Canada, 29% to Mexico, and 29% to Asia (USDA-FAS). Some increase in exports seems possible, particularly to Asia, but selling a large proportion of the increase resulting from our growing ethanol production to other countries seems unlikely. In addition to feeding and exporting more of the coproduct feeds, they may be used for fuel to provide heat in operating the ethanol plants, or they may be gasified either for boiler fuel or to provide a feedstock to produce more ethanol. While other uses, including for fertilizer and to manufacture fiber board, have been suggested, combustion and gasification appear to be the major competition for use of these products by the livestock and poultry industry.

Biodiesel Production Costs and Profitability

The majority of the current biodiesel supply is produced using a continuous flow process. These plants produce two coproducts, biodiesel, which is sold on the market, and glycerol, which currently has a very limited market. The continuous flow processes have somewhat higher capital costs, but they have lower processing costs and more consistent output than the batch processes used in the initial plants. They are better suited to virgin feedstocks that are of consistent quality, and the feedstock can be sourced from a wider geographic area. It has been estimated that about 90% of the current biodiesel is produced from soybean oil (Collins). However, many of the new plants are designed to handle multiple or combination feedstocks.

Investment and Cost per Gallon

In a recent study, Ginder and Paulson report the capital requirements to build and start up turn-key biodiesel plants. They report the initial capital required is $1.47 per gallon of annual capacity for a 30 million gallon per year biodiesel facility, and $1.10 per gallon of capacity for a 60 million gallon per year plant.

Table 4. Estimated Cost of Biodiesel Production from Soybean Oil for New Plant Construction

	Annual Plant Capacity	
Degummed Soybean Oil ($/lb)	30 Million Gallons ($/Gallon)	60 Million Gallons ($/Gallon)
0.20	1.98	1.90
0.25	2.35	2.27
0.30	2.72	2.64
0.35	3.09	3.01

They also estimate the nonfeedstock production costs. Using their investment and operating costs, and assuming a 12% rate of return and a 10-year capital recovery period, the operating and capital costs per gallon are $0.50 and $0.42 for the two sizes of plants, respectively. Like ethanol plants, biodiesel plants seem to exhibit significant economies of size.

The major cost in producing biodiesel is the cost of the feedstock. One gallon of biodiesel requires 7.4 pounds of degummed soybean oil. With a cost of $0.30 per pound, the cost is $2.72 in a 30 million gallon per year plant (Table 4). The plant should also be eligible for the small producer credit. If the plant is operated at capacity for the year, the small plant credit would average $0.05 per gallon. The larger plant has lower costs per gallon and as well is eligible for the small producer credit. Including the $1.5 million small producer tax credit for both plant sizes reduces the cost advantage of the larger plant from $0.08 to $0.055 per gallon.

Biodiesel Price

The average relationship between the monthly average refiners acquisition cost of crude oil and the monthly average wholesale price of no. 2 diesel fuel is given by Equation (2). This relationship accounts for much of the variation in the monthly average diesel fuel price (R^2 = 0.97) over the period January 2000 through October 2006. Like gasoline, the wholesale price in any month is influenced by seasonal factors and unexpected supply

Table 5. Estimated Average Wholesale No. 2 Diesel Fuel Price

Refiners Acquisition Cost ($/Barrel)	Wholesale No. 2 Diesel Price ($/Gallon)
40	1.25
50	1.59
60	1.93
70	2.26
80	2.60

and demand factors. The relationship indicates the monthly average price of no. 2 diesel fuel with $60 per barrel crude oil is $1.93 per gallon, with the price

$$(2)\quad \underset{(0.0906)}{WP_D} = \underset{(0.0265)}{-0.0908} + \underset{(0.0007)}{0.0336P_C},$$

where

WP_D = monthly average wholesale price of no. 2 diesel fuel in $/gallon,

increasing (decreasing) $0.336 with each $10 increase (decrease) in the acquisition cost of crude oil (Table 5).

U.S. average biodiesel prices since January 2005 have been averaging about $1.25 above the U.S. average wholesale price of diesel fuel (Figure 2). Purchasers of biodiesel have received $1.00 of this difference through the refund of the volumetric excise tax credit, indicating biodiesel has been selling at a premium of about $0.25 per gallon. Assuming the biodiesel producer has marketing and transportation costs of about $0.20 per gallon, the netback price when crude oil is $60 per barrel should average about $2.98 ($1.93 + 1.25 − 0.20) per gallon. This would provide an additional profit of $0.26 per gallon when the production cost is $2.72 per gallon.

What Biodiesel Plants Can Afford to Pay for Feedstock

The above analysis suggests the plant could pay more than $0.30 per pound for the degummed soybean oil used as the feedstock for producing the biodiesel. The amount they could pay and just earn the 12% rate of return can be determined for the 30 million gallon

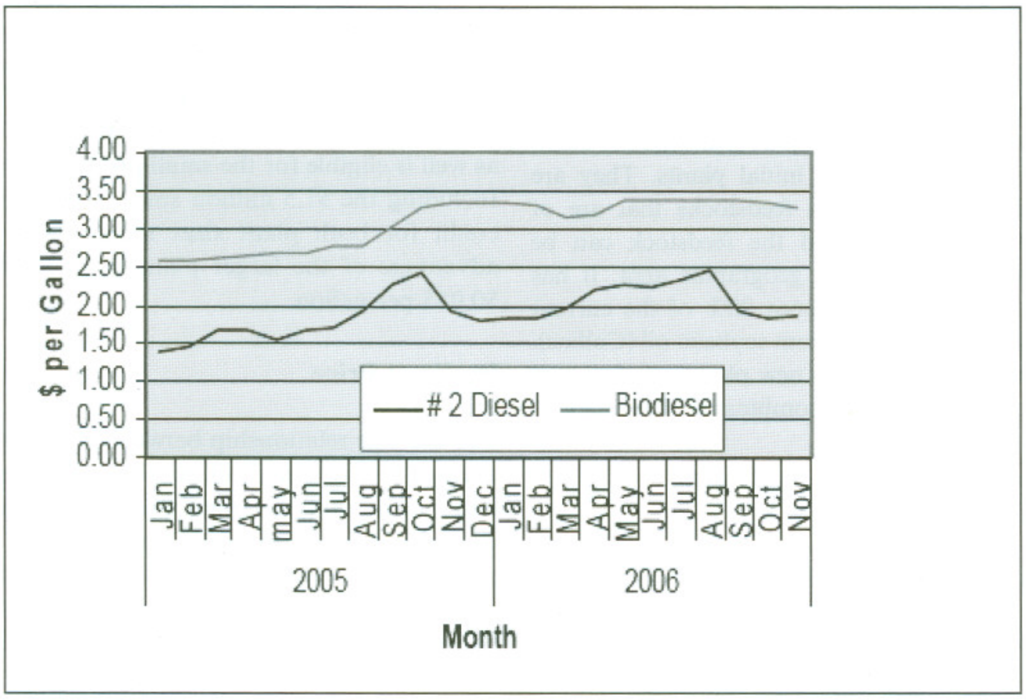

Figure 2. United States Monthly Average Diesel and Biodiesel Prices

per year plant using Equation (3):

$$P_{SBO} = (WP_D + ETC + PP - OCC - MTC)/Q_{SBO}/\text{Gal}, \quad (3)$$

where

P_{SBO} = price per pound of soybean oil to earn a normal (12%) rate of return
ETC = the excise tax credit per gallon of biodiesel ($1.00 for virgin oils)
PP = price premium expected per gallon for biodiesel (estimated at $0.25 above)
OCC = operating and capital costs per gallon ($0.50 for 30 million gallon plant)
MTC = marketing and transportation cost per gallon ($0.20)
Q_{SBO}/Gal = pounds of soybean oil per gallon of biodiesel (7.4).

If crude oil is $60 per barrel, the estimated price of no. 2 diesel fuel is $1.93. Substituting this into the above equation and solving indicates the 30 million gallon plant could pay $0.335 per pound of soybean oil and make the 12% rate of return. The larger plant has lower cost ($0.42 instead of $0.50) and could pay $0.346 per pound. With crude oil at $50 and $70 per barrel the breakeven degummed soybean oil prices would be $0.289 and $0.380 per pound for the 30 million gallon plant. The larger plant could pay 1.1 cents more per pound at each price level.

Continued growth of the biodiesel industry is highly dependent on continuation of the volumetric excise tax credit or some other subsidy to replace it. The industry grew very slowly before the availability of the credit at the beginning of 2005, filling niche markets for fleets of government vehicles and for use in engines where the environmental benefits are very important, including marine craft, and engines in mines and other enclosed areas. During 2005 and 2006 the number of distributors and retailers selling biodiesel increased dramatically, greatly increasing its availability to the consuming public across the country (National Biodiesel Board). Some gains in production efficiency can be made with larger processing facilities and more efficient markets to collect and move the feedstocks to the plants. However, these gains will not be sufficient to replace the excise tax credit that has fueled the growth of the industry over the past two years.

Table 6. U.S. Supply of Vegetable Oils and Animal Fats

Oil/Fat Type	Million Pounds[a]	Million Gallons[b]
Vegetable oils		
Soybean oil	18,309	2,446
Cottonseed oil	847	113
Sunflower oil	558	74
Peanut oil	84	11
Corn oil	2,436	325
Canola oil	603	80
Total	22,836	3,044
Yellow and brown grease	2,656	332
Animal fats		
Lard	1,090	131
Edible tallow	1,894	228
Inedible tallow	3,696	445
Poultry fat	4,204	507
Total	13,540	1,643
Total Supply	36,376	4,687

[a] Pounds of oil are 2000–2004 average from Bureau of the Census and Agricultural Marketing Service, USDA. Pounds of yellow and brown grease and inedible tallow are a 2000–2003 average from U.S. Department of Commerce, U.S. Census Bureau, *Current Industrial Report*, M311k (03)-13, March 2005. Poultry fat estimate is based on the average slaughter for 2000–2004, USDA.

[b] Potential gallons of biodiesel are computed using a conversion ratio of 7.5 pounds for vegetable oils, 8 pounds for yellow and brown grease, and 8.3 pounds for lard, tallow, and poultry fat.

Supply of Biodiesel Feedstocks

The supply of biodiesel feedstocks is a major factor limiting the development of the biodiesel industry. Table 6 lists the average annual production of vegetable oils and animal fats in the United States. The United States produces about 36.4 billion pounds of vegetable oils and animal fats per year. The numbers in the right column of Table 6 indicate that converting the entire annual supply of vegetable oils and animal fats to biodiesel would produce only 4,687 million gallons, about 11% of the annual diesel use in the United States. Of course, much of the vegetable oil and animal fat supply is used in producing food and industrial products, and only a portion of the supply could be bid away to produce fuel.

To estimate the size of a sustainable feedstock supply for biodiesel production, it is useful to consider the feedstock in three categories, vegetable oils, yellow and brown grease, and the animal fats. Notice that soybean oil is the dominate vegetable oil, making up 80% of the annual vegetable oils produced in the United States. This was the major feedstock used to produce 250 million gallons of biodiesel last year. Expanding much beyond this level would seem to require crushing a larger percentage of the soybean crop and shifting some of the exports from soybeans to soybean meal. With a larger crush the supply from soybean oil may be as large as 500 to 600 million gallons, with an additional 50 million gallons produced from other vegetable oils.

Yellow grease and brown grease, the used cooking fats, are a second type of feedstock that can be used to make biodiesel. However, the supply is spread across the country in food service firms, limiting the opportunities to collect and process sufficient quantities to provide a biodiesel manufacturer with a continuous supply for a large-scale plant. These oils are commonly used in animal feeds and soaps, which will be competitive for the supply. With some time to develop the infrastructure to assemble and process grease into a suitable feedstock supply and to find substitutes to replace its lower value uses, perhaps two-thirds of this source can be bid away to produce an additional 200 million gallons of biodiesel.

The animal fats are a third category of feedstocks for biodiesel production. While the annual supply is relatively large, the cold weather qualities of the resulting biodiesel limit their use, at least for transportation fuels. Although they may produce biodiesel for use in heating fuels or in stationary engines where the fuel supply can be kept warm, some inexpensive additives are needed to reduce their cloud point and pour point before they can be considered for use in transportation fuels in much of the country. Processing about one-half of the inedible tallow and poultry fat would provide feedstock for an additional 450 to 500 million gallons of biodiesel production per year.

These data suggest the United States could produce up to 1,200 to 1,300 million gallons of biodiesel annually from domestic vegetable oils and animal fats. It should be emphasized that about half of this total would be of very limited use for transportation fuels because of its cold flow properties.

In addition, the adoption of the technology to remove corn oil from thin stillage and fractionation by dry-mill ethanol plants will add to the supply of corn oil available for biodiesel. As the ethanol industry adopts these technologies it will provide enough corn oil to produce 71 million gallons of biodiesel per billion gallons of ethanol produced by the dry mill plants adopting these technologies.

Summary

Ethanol production has increased at a rapid pace in recent years, reaching 4.9 billion gallons in 2006. The industry is expected to bring even larger amounts of capacity on line during 2007 and 2008, with production reaching 11 billion gallons in 2009. Biodiesel has tripled production each of the past two years, reaching 250 million gallons in 2006. Many have questioned the impact of these rapid rates of expansion on the price of feedstock and the profitability of the industries over the next several years. This article reviews three factors that will be of major importance in determining the profitability of these industries over time: policy, the price of the feedstock (corn, vegetable oils and animal fats), and the price of petroleum.

The volumetric ethanol excise tax and the small producer (income) tax credit are very important to the profitability of the ethanol industry, particularly as the price of petroleum moves below $50 per barrel. VEET provides a $0.51 per gallon blenders fee that supports the market price of ethanol, while the small producer tax credit provides an annual income tax credit that partially offsets the economies of scale enjoyed by plants producing more than 60 million gallons annually. Biodiesel also benefits from an excise tax credit of $1.00 per gallon and the same small producer income tax credit. The importance of the excise tax credit is underlined by noting the large increase in sales that occurred after it went into effect at the beginning of 2005.

The cost of building ethanol plants has increased about 50% over the past two years, largely because of increases in the price of stainless steel, copper, and concrete. With corn at $3.00 per bushel and the higher capital costs, the net cost of ethanol is $1.66 per gallon for a plant with 60 million gallons of annual capacity and $1.57 for a 120 million gallon plant. The net cost increases $0.26 for each $1.00 increase in the price of corn. If the plant netback price of ethanol is $1.89 per gallon (my estimate of the average netback price with crude oil at $60 per barrel), the 60 million and 120 million gallon plants will earn normal returns purchasing corn for $3.90 and $4.25 per bushel, respectively. They would be willing to pay more than $5.00 per bushel in the short run before shutting down an existing plant.

Marketing the coproduct feeds will be an increasing challenge, particularly as production exceeds 10 billion gallons. The introduction of fractionation technologies by some dry mill plants and processes to remove the oil from the thin stillage by others will reduce the quantity of coproduct feeds and increase the array of feed products. The wider array of feed products should enhance the efficient use of the coproduct feeds in livestock and poultry diets.

Biodiesel production costs also exhibit economies of scale. When the market price of degummed soybean oil is $0.30 per pound, the cost of producing biodiesel is $2.72 and $2.64 per gallon with a 30 and 60 million gallon per year plant, respectively. When the price the plant receives is $2.98 (my estimated average biodiesel price when petroleum is $60 per barrel), the analysis indicates the small plant could pay $0.335 per pound for degummed soybean oil and earn normal profits. With petroleum at $50 per barrel, the price resulting in normal profits for the small plant is $0.289 per pound.

The supply of feedstocks is a major factor limiting the growth of the biodiesel industry. However, the adoption of fractionation and the technology to remove corn oil from thin stillage by dry-mill ethanol plants will increase the supply of oil for biodiesel production.

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