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Ethanol and U.S. Agriculture

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Ethanol produced from grain is viewed by many as a way to reduce energy imports, levels of carbon monoxide in the air, and surplus grain stocks. Federal and State governments helped to establish the fuel ethanol industry by providing direct payments, tax exemptions, and loan guarantees. Future policy decisions could significantly affect ethanol production and demand. Treatment of ethanol in agricultural policy is made difficult by its ties to energy, environmental, and trade policy. This bulletin provides a basis for assessing the contribution of ethanol production to national objectives.

Reacting to the energy crisis caused by the 1973 petroleum embargo, many Americans focused on reducing the Nation's dependence on imported oil and diversifying the sources of energy supplies. Ethanol, used as an alcohol fuel to substitute for or enhance petroleum, held the promise of becoming a new renewable domestic source of energy. Ethanol gained support as it also promised environmental benefits and new markets and uses for corn and other surplus crops. But the sense of urgency over the need to develop alternative fuels dissipated as petroleum prices declined.

Public attention has again focused on alcohol fuels to help reduce pollution, dependence on foreign oil, and crop surpluses. Compliance deadlines of the Clean Air Act passed and the standards are still unmet. U.S. petroleum imports have increased to the high levels of the early 1970's. Ethanol's success in helping to solve those problems depends on energy, environmental, agricultural, and trade policies that will determine the prices, costs, and competitiveness of the new industry.

Competitiveness of the Industry

The U.S. fuel ethanol industry was created by a mix of Federal and State subsidies, loan programs, and other incentives. This industry, while relatively new, has grown rapidly. Plants producing alcohol fuel vary by size, type of technology, feedstock, financing, type of equipment, byproducts, and operating experience (see box).

A small number of facilities produces most of the ethanol. The eight largest plants, owned by the five largest ethanol-producing firms, accounted for nearly 75 percent of operating capacity in 1986. Only 17 of over 150 fuel ethanol plants built since 1979 have a capacity to produce at least 10 million gallons per year (mgy). Most commercial plants produce at least 1 mgy, although a few onfarm plants produce 0.05 to 0.5 mgy. Plants of less than 10 mgy are categorized as small, plants in the 10-39 mgy range as midsized, and plants above 40 mgy as large.

The Federal Government helped develop the industry by providing tax exemptions and loan guarantees. The Government's largest financial incentive was exempting ethanol/gasoline blends from at least part of the excise tax on fuel. The excise tax level and the exemption have both risen. Ethanol is exempt from 6 cents of the 9-cent tax through September 1993. At the 10-percent blending rate allowed under fuel standards, that exemption is effectively a 60-cent-per-gallon subsidy. Many States provide similar financial incentives averaging 20-30 cents per gallon.

The Government has also provided loan guarantees to encourage plant construction. Federally financed plants constitute about 25 percent of industry capacity. Most of the plants built with federally guaranteed loans are relatively small, producing under 40 mgy.

But, most of these plants have not been successful. Only 5 of the 13 plants with loans guaranteed by

How Ethanol is Produced

Fuel ethanol is produced by converting crops containing starch or fermentable sugar to alcohol and is used as a gasoline extender or octane enhancer. Corn has been the principal raw material (feedstock) because it is readily available, stores well (facilitating year-round production), and has been relatively inexpensive.

The basic steps of processing corn, for example, into ethanol are milling, separating starch, converting to sugars, fermenting, distilling, and dehydrating. The process also generates carbon dioxide, corn oil, and protein feeds as byproducts.

Ethanol can be produced in a wet mill or a dry mill. A dry mill can have lower initial construction costs but the process generates lower valued byproducts, such as distillers dried grains (DDG), used to supplement animal feed. A wet mill is often built in conjunction with a plant that produces high-fructose corn syrup. While more expensive to build and operate, wet mills generate a greater variety of products, such as beverage sweeteners and ethanol, and byproducts for animal feed, such as corn gluten feed and corn gluten meal, providing greater flexibility in choice of output.

USDA's Farmers Home Administration have either paid off the loan or were making repayments as of early 1988. Only one of the three plants with loans guaranteed by the Department of Energy was operating and paying off its loans in early 1988.

The poor showing by federally guaranteed plants mirrors the problems facing the industry. Many privately financed plants built over the last 10 years have closed and gone out of business. The relatively high failure rate in the industry stems from the falling price of petroleum, varying net corn costs, unsuccessful designs of some early plants, lack of experience in grain handling, and lack of experience in producing a high volume and relatively low unit value fuel.

Production Costs

Ethanol production costs vary widely over time and among existing plants. Costs per gallon of ethanol produced by larger facilities are relatively less than for small facilities as they achieve economies of scale in the production technology and distribution of the product. The financial resources of larger producers enable the ethanol industry to compete with the petroleum and petrochemicals industries.

Large plants will likely continue to dominate the ethanol industry. But, small plants with annual capacities of 0.5-10 mgy can be profitable under favorable local conditions:

- Low feedstock prices made possible by locating the plants in areas with high transportation costs to major grain markets,
- Low feedstock prices by locating near food processing facilities where fermentable wastes are produced, and
- Low energy prices by locating near a feedlot thereby allowing the undried byproducts to be fed directly to the cattle.

Total production costs are the sum of capital and noncapital costs (noncapital costs can be broken down further into operating and net corn costs). The cost of producing ethanol depends on highly variable purchase prices for corn and selling prices for byproducts, such as high-protein feeds. Producers benefit when byproduct prices are high and market corn prices are low. The calculated full cost of production from a stand-alone plant has ranged from as low as $0.75 per gallon with the unusually high byproduct prices of early 1987 to $1.40-$1.50 during 1981, 1983, and 1984.

Net corn cost is the single largest component of noncapital costs. The net cost of corn, the cost of corn minus byproduct prices, has varied more than either the market price of corn or the byproduct prices. Corn prices have consistently fallen over the last 8 years until drought conditions developed in 1988 (fig. 1). Byproduct sales have offset as little as 30 percent of the corn cost for dry mills and as much as 90 percent of the corn cost for wet mills in early 1987.

Operating costs other than corn costs vary considerably by plant size. These costs include energy, ingredients, personnel, maintenance, management, insurance, and taxes. Large plants incur operating costs of 40-59 cents per gallon of ethanol produced. Costs for small and midsized plants vary more markedly, 32-65 cents per gallon. Energy is the greatest outlay, averaging 36 percent of operating costs. Costs, particularly energy and labor costs, tend to be 5-10 cents per gallon higher for small and midsized plants, except where they can exploit favorable local economic conditions.

Capital charges range from 19 cents to 48 cents per gallon under the latest tax laws. In estimating production costs, one must examine the average operating level of the plant relative to its rated capacity: our estimates assume plants operate at full capacity. Large plants have consistently produced at or above rated capacity. Midsized and small plants have shown mixed operating records, therefore generally incurring higher production costs.

Technological Improvements

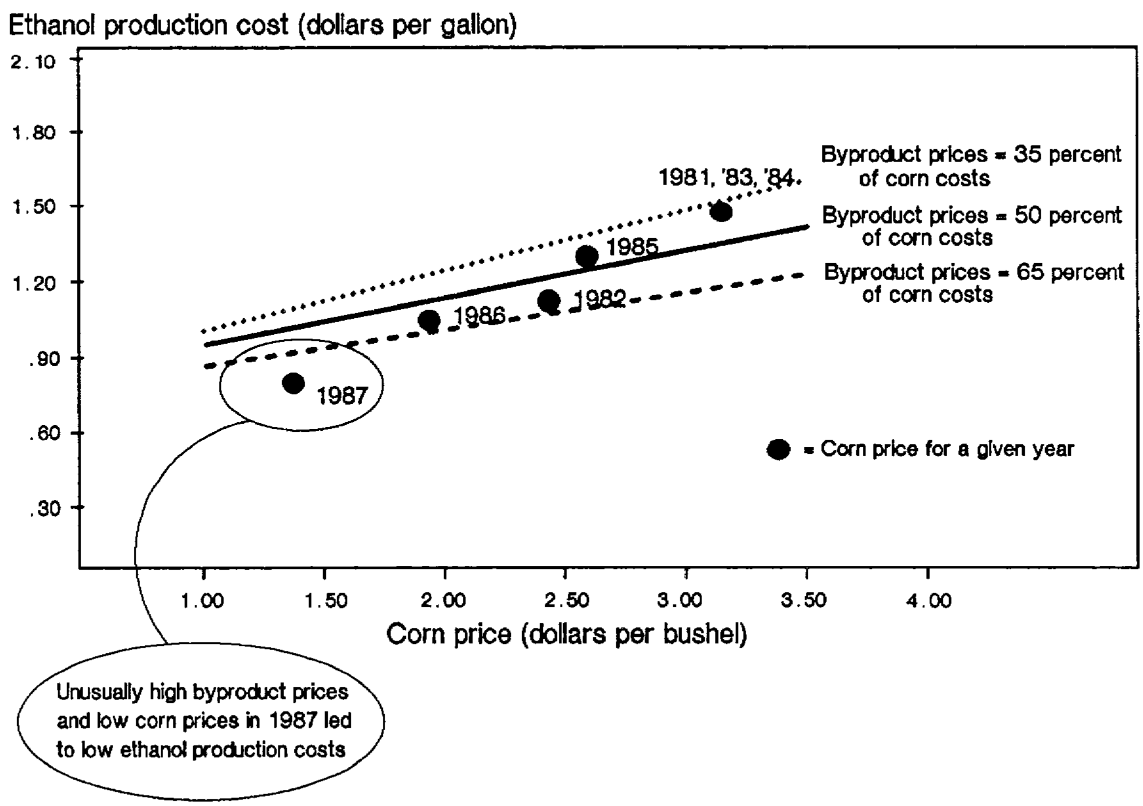
There is considerable room for improving the cost and efficiency of producing fuel ethanol because the technology used in large-scale production of liquid alcohol is relatively new. Industry savings of even a few cents per gallon of output are significant. We evaluate developments that could reduce costs both in the short and long term. A state-of-the-art plant can produce ethanol with lower operating costs than existing plants, primarily from reductions in costs of energy, management, administration, insurance, and taxes (table 1). Three new technologies could lower operating costs but the technologies are still considered to be experimental and, therefore, not proven in commercial-scale production:

- Substituting yeast with the bacteria, *Zymomonous mobilis,* in the production process can potentially speed fermentation. In the laboratory, this bacteria can tolerate more extreme temperatures (so less attention would be needed for temperature control in commercial production).

- Using a permeable membrane to separate out the dissolved solids before boiling may greatly reduce the energy needed for distillation because up to 40 percent of the water may be removed along with the solids.

- Immobilizing the yeasts and enzymes in the wet-mill process, whereby the starch or sugar solution passes through a medium containing the enzymes and yeast (or bacteria), may reduce fermentation and contamination problems. This method may substitute for yeast recycling in wet mills and improve control over the process by maximizing the use of yeast and enzymes.

Figure 1. Higher byproduct prices partially recoup variation in corn costs for ethanol producers



Other technologies need refining to provide payoffs. Using other crops with fermentable starch and sugar contents, such as Jerusalem artichokes, sugar beets, fodder beets, and sweet sorghum, could help insulate ethanol production from shifts in corn prices. Ethanol yield from corn, grain sorghum, and wheat currently surpasses that of other grain and starch crops. Should corn prices rise, the alternative feedstocks may become relatively cheaper because they can be grown under soil and climatic conditions less suitable for corn production. Bioengineering and traditional plant breeding technologies that increase per acre yields or increase starch and sugar contents of corn and other crops may also lower ethanol costs by reducing feedstock costs.

The major focus of much ethanol research and development has been in developing ways to convert cellulosic biomass materials into sugars that can be fermented. The most promising technologies are those that convert herbaceous plant material like alfalfa, corn stover, and bagasse into ethanol. Current technologies for converting herbaceous and woody biomass to ethanol are not competitive with the technology used to convert grain to ethanol given low grain prices. But, the new technologies to convert biomass into ethanol can also generate a variety of chemical products with market values higher than ethanol. If these technologies prove successful, ethanol may become a relatively minor byproduct with demand for other chemical products driving production.

It is difficult to predict cost savings associated with potential technological improvements. The state-of-the-art plant in 3-5 years may save an additional 5 cents per gallon in operating costs over today's state-of-the-art plant without substantial changes in capital costs.

Table 1—Operating costs are lower for state-of-the-art plants than for current average plants

Production costs	Current average	State-of-the-art
	Dollars per gallon	
Energy	0.17	0.11
Ingredients, personnel, and maintenance	.24	.24
Management, administration, insurance, and taxes	.06	.03
Total	.47	.38

19% lower total operating costs

The best current processing cost estimates for alcohol and complementary products from cellulose range between $1.00-$1.20 per gallon compared with between $0.60-$0.90 per gallon for a grain plant at $2 per bushel corn prices.

Figure 2 captures how changes in grain and crude oil prices may affect ethanol production costs with and without a Federal subsidy for ethanol. With $2 per bushel corn and the existing Federal subsidy, ethanol produced using average existing technology is competitive if crude oil trades at about $24 per barrel or higher. If state-of-the-art technology is used, ethanol becomes competitive when crude oil is $20 per barrel. With further technological improvements in the next few years, ethanol could become competitive with crude oil at $18 per barrel. With state-of-the-art technology but without a Federal subsidy, ethanol would not be competitive until crude oil prices reach at least $40 per barrel.

Ethanol In U.S. Energy Policy

Energy policy provides for short- and long-term energy stability, that is, energy security, for the Nation. Policies for long-term energy security have been aimed at improving research and development and at assuring timely commercial production of alternative fuels based on plentiful domestic resources.

The Federal Government has provided subsidies to develop all domestic energy resources, including ethanol (table 2). Ethanol is subsidized more than

Table 2—The Government has historically provided incentives for all types of energy production

Energy resources and technologies	Government incentives for energy production	
	1977	1984
	Dollars per million Btu's	
Crude oil and liquid natural gas	1.23	0.02
Natural gas	-.07	.28
Coal	.12	.19
Ethanol	ND	15.78
Nuclear	3.29	15.33
Electricity	1.12	1.28
Hydroelectric	.81	2.58

Note: 1986 dollars.
ND = Not defined.

The subsidies for ethanol production are more than 50 times greater than that for oil, gas, or coal other fuels. The 1984 ethanol subsidy of approximately $15 per million Btu's is more than 50 times greater than that of petroleum, natural gas, or coal. However, it is difficult to interpret the relative subsidy levels because some general categories mask research and development projects that had little or no attributable output in the year the funds were spent.

Concern over the Nation's energy security might prompt enactment of policies that lead us to depend less on foreign oil supplies and more on our own resources. But, such a move might hurt more than help. Energy independence gained by forcing consumption of relatively expensive domestic fuels could retard economic growth and eventually deplete domestic nonrenewable natural resources, such as natural gas. Even with reduced dependence on foreign supplies, spiraling international energy prices could reduce global income and output, which reduces international trade. Lower income abroad could reduce demand for U.S. exports, hurting domestic exporters and producers and, therefore, the U.S. economy.

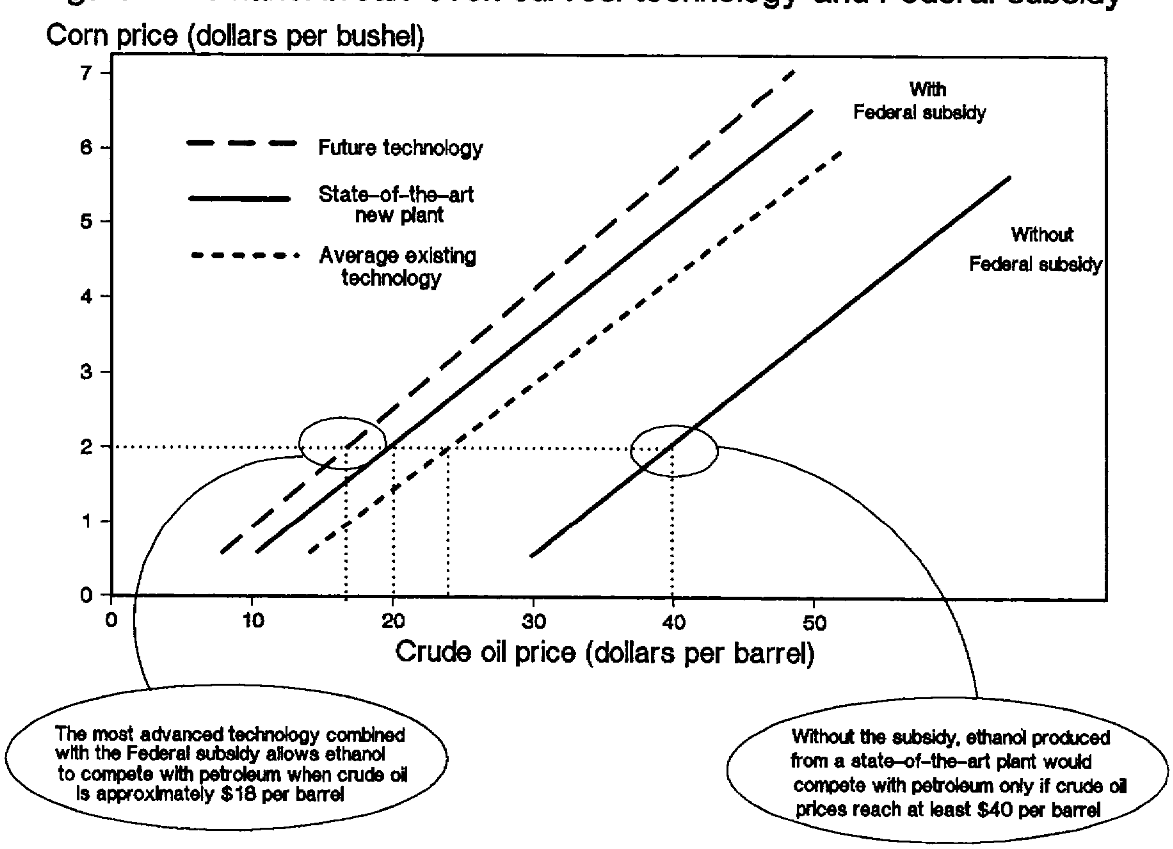
The cost range for producing ethanol reflects uncertainty over future price increases in ethanol feedstocks. At present, ethanol is produced from agricultural grains and organic waste. Even if research and development significantly reduce feedstock costs, the cost of large-scale biomass use would remain high in terms of traditional inputs and disruptions of the environment. Also, producing a large amount of ethanol could drive up feedstock prices and its own cost of production. Biomass fuels such as ethanol will likely be more expensive with smaller quantities available over the next 100 years or more compared with liquid fuels from coal and shale oil.

Alternative Fuels and Air Quality

Interest in alcohol fuels has been renewed as many metropolitan areas have failed to meet compliance deadlines of the amended Clean Air Act and as using alcohol in vehicle engines has been perceived as a painless way to reduce emissions. But, alcohol fuels from ethanol are not necessarily safer to the environment in all cases than fuels produced entirely from petroleum.

Most vehicles can use ethanol blends without modified engine designs because blended alcohol fuels are

Figure 2. Ethanol break-even curves: technology and Federal subsidy



similar enough to straight gasoline. But alcohol-blended fuels consist primarily of gasoline, which limits the potential benefits of the emission control and efficiency of the alcohol additive.

The amended Clean Air Act requires that concentrations of lead, sulfur dioxide, nitrogen dioxide, ozone, carbon monoxide, and particulate matter not exceed national standards. The act requires States in areas where concentrations of those pollutants exceed the standards to develop plans to control emission sources and meet the standards. Levels of lead, sulfur dioxide, and nitrogen dioxide have met or are nearing the standards, but ozone and carbon monoxide are still serious problems in many areas.

Using alternative fuels will directly affect emissions from motor vehicles. The Environmental Protection Agency (EPA) attributes 66 percent of all carbon monoxide emissions to imperfect combustion in motor vehicle engines. That share exceeds 80 percent in many urban areas. Motor vehicles also significantly increase ozone pollution. Ozone is not directly emitted by vehicles but forms in the air by the reaction of volatile, organic compounds in the presence of sunlight. The level of ozone-producing compounds emitted by vehicles varies considerably among cities.

Unlike the carbon monoxide trend, the ozone trend line was above the EPA goal from 1976 to 1985. The national carbon monoxide levels declined 36 percent in that period, with the greatest declines recorded recently. Ozone pollution (mainly a summertime problem) declined during the period to about the mean level called for by the standard. By 1995, fewer than 50 percent of the urban areas now exceeding the ozone goal are expected to comply with the EPA goal, compared with 80-90 percent of the urban areas currently exceeding the carbon monoxide goal.

Adding ethanol to gasoline increases fuel volatility and thus increases the amount of evaporative hydrocarbon emissions. At a 10-percent blending level for ethanol, fuel volatility (as measured by Reid vapor pressure) increases by 1-2 pounds per square inch. The presence of alcohol in the blend promotes greater evaporation than when the gasoline is not blended. Without compensating changes in fuel formation, widespread adoption of alcohol fuels would increase the evaporation problem and local ozone levels.

Using ethanol blends may reduce carbon monoxide levels but also may increase nitrogen oxides, which produce ozone in the presence of sunlight. Even if hydrocarbon emissions do not increase because of the more volatile ethanol blends, the higher nitrogen oxide emissions may encourage more ozone to form. This effect is particularly important in the warmer months in most parts of the country and almost all year in southern California, parts of Arizona, and the Gulf Coast States. Ozone is considered to be a more difficult pollution problem to treat than is carbon monoxide.

The Colorado Air Quality Control Commission mandates the use of oxygenated gasoline fuels (such as gasoline/ethanol blends) to reduce levels of carbon monoxide and particulate emissions. The program is in effect during the winter months, when ozone pollution problems are usually the mildest. The mandated blended fuels program is only one of many measures to reduce carbon monoxide pollution in Denver and surrounding counties in Colorado's Front Range. But, Denver and surrounding areas will probably not meet the EPA carbon monoxide standard even with innovative programs supplementing the oxygenated fuels program.

Other States, including Arizona and New Mexico, have recently enacted oxygenated fuels programs to meet the EPA standards for carbon monoxide levels. While using blended gasoline may initially decrease carbon monoxide levels 3-10 percent at sea level and as much as 20 percent at high altitudes, the rate at which carbon monoxide levels continue to decline may slow as population and the number of vehicles grow, possibly reversing the improvement in air quality in these areas.

Ethanol and Agriculture

Ethanol production affects both the demand for and supply of grain. The demand for corn rises with increases in ethanol production because corn is used as a feedstock. This increased demand can help reduce excess domestic grain stocks by partially substituting for traditional agricultural programs, which have relied on price supports, supply control, and grain reserves. The importance of ethanol production for agriculture depends on commodity markets, the nature of farm programs, and the size of the ethanol industry. Ethanol production would have a greater effect on commodity prices and production under tight market conditions of high prices and low stocks for corn than under soft market conditions of low prices and large stocks. Ethanol takes on added importance as an alternative use for corn in times of low export demand.

Ethanol production also increases the supply of high-protein animal feeds from the byproducts. Dry milling produces about 18 pounds of DDG for every bushel of corn converted to ethanol plus carbon dioxide. Wet milling produces 2.5 pounds of gluten meal (60 percent crude protein), 12.5 pounds of gluten feed (20-21 percent crude protein), germ which is converted to 1.6 pounds of corn oil, and carbon dioxide.

Corn, Oilseed, and Byproduct Markets

Increased ethanol production increases corn prices. The size of the increase depends on how much corn ethanol producers use and the ability and willingness of farmers to shift acreage into corn production. Farmers would be expected to plant more corn but at the expense of soybeans, depending on the market price of corn and the set of Government incentives in place. Farmers will shift production because corn will be priced higher. The demand for oilseeds, including soybeans, cottonseed, and sunflower seeds, will fall because of competition from ethanol byproduct feeds. Falling prices for these crops further enhance the relative profitability of corn.

Future expansion will determine the amount of corn demanded by the industry. Capacity expansion would be modest if the Federal excise tax exemption expires in 1993, leaving only minor economic incentives to expand. Expectations that the tax exemption will expire will likely cause production to plateau at about 1 billion gallons of ethanol within the next few years, about half the level expected to be produced if the subsidy were to continue. Ethanol production under minor expansion would have only a negligible effect on corn prices.

Increased ethanol production would lower oilseed and protein market prices as greater quantities of protein feed and corn oil byproducts are supplied. For example, soybean market prices would initially decrease if ethanol production increases significantly. However, soybean supply would shrink and partially offset the fall in soybean prices as farmers substitute corn for soybean acreage. Corn prices relative to soybean prices would ultimately move back toward their long-term relationship reflecting relative production costs.

An additional 800 million bushels of corn could be needed by the industry if ethanol production increases to triple the current levels of production by 1995, perhaps initially increasing corn prices by 50 cents per bushel. The increase would moderate to 35 cents as corn production and the agricultural sector adjust to the higher demand. Production of ethanol byproducts could reach 5 million tons (20 percent of soybean meal currently produced), with over 800 million pounds of corn oil generated (7 percent of current oil production).

Increased production of ethanol would also generate more byproducts. Domestic feed markets can absorb the additional byproducts. However, resulting lower byproduct prices would decrease ethanol profitability.

The likelihood that byproduct feeds would receive a protein-equivalent price decreases significantly if ethanol production were significantly expanded and exports were restricted. For example, the European Community (EC) is the largest foreign market for U.S. gluten feeds. Ninety-five percent of such EC imports come from the United States, free of tariffs and duties. The EC has proposed to limit annual imports of corn gluten feed to 3 million metric tons, about 1 million less than current annual U.S. exports, to support the demand for EC grains. Restricting imports would lower the profitability of producing ethanol in the United States by reducing the value of U.S. ethanol byproducts.

Farm Income

Changes in grain prices brought about by ethanol production have not significantly affected income for farmers participating in Government commodity programs. In fact, current farm commodity programs buffer participating farmers from changing market prices. Commodity programs guarantee farmers a fixed target price for their crops. For farmers not participating in farm programs, any price change affects income.

Changes in income due to increased ethanol production would vary among grain, oilseed, and livestock producers. The resulting higher demand for corn would increase corn prices at the expense of soybean and other oilseed prices.

Grain producers as a group may increase net income, but some livestock producers may be hurt if they cannot substitute lower priced livestock feeds for the higher priced grains. Livestock producers who avoid higher corn prices could increase their incomes by using lower priced byproduct feeds and expanding their operations, but the combined changes in revenue and income are minor.

Moderate levels of ethanol production would only slightly affect total farm revenue and income. It is unlikely that modest increases in ethanol production would drive market prices for corn to exceed current target price levels within the next 8-10 years. If ethanol production grew moderately to approximately three times the current production level within the next decade, total gains to farm income would be less than

$1 billion, less than 5 percent of 1986 net farm income. Gains to crop producers generally would offset losses to livestock producers. Crop farmers specializing in corn, sorghum, and wheat would gain while those specializing in soybeans or those who combine cotton and soybeans would lose.

Future Issues

Forthcoming changes in agricultural, energy, environmental, and trade policies could significantly affect ethanol production. Modifying existing agricultural policy, including price support programs, could affect the cost of producing ethanol through changes in corn supplies and prices. The demand and price for corn could rise if the use of ethanol/gasoline blends were to increase substantially because of changes in energy or environmental policies. Higher demand and prices could shift the farm sector from price supports to greater reliance on agricultural markets, possibly resulting in savings to the U.S. Treasury. However, higher corn prices resulting from expanded ethanol production would not be without cost: a motor fuel excise tax exemption supports ethanol but at the expense of revenues to the U.S. Treasury.

Patterns of U.S. ethanol production and distribution respond to changes in trade policy. Ethanol imports have been discouraged through a 60-cent-per-gallon tariff plus a 3-percent tax in proportion to the value. Since January 1987, duty-free ethanol could enter the United States from the Caribbean Basin only if feedstocks for 60 percent or more of the total ethanol processed originated from the Basin. Waivers from this restriction were granted to two production facilities in 1987, and three additional facilities in the Basin as part of the U.S. trade act passed in the summer of 1988. The waivers are now in effect through 1989. Each facility is limited to exporting 20 million gallons of ethanol per year to the United States duty free. Larger ethanol imports from the Caribbean Basin can be expected if the restrictions are lifted in the future. Caribbean ethanol entering without tariffs would carry a relatively low price since it is processed from surplus stocks of European wine, a relatively cheap feedstock. Existing patterns of producing and distributing ethanol would change in response to cheaper imports since Caribbean ethanol can be easily transported to the Gulf and East Coast States.

International ethanol trade patterns could also change under liberalized trade conditions, as proposed at the GATT (General Agreement on Tariffs and Trade) negotiations. Under free trade, more ethanol could be imported directly from Europe, including France and Italy which produce ethanol from surplus wine stocks. U.S. ethanol would also have a potentially wider market under free trade as existing tariffs in Europe would be suspended. Trade would depend on the comparative advantage in producing ethanol in various countries. Cost and availability of feedstocks would be an important determinant.

For Additional Information...

Contact Sally Kane or Michael LeBlanc (at 202/786-1405), Resources and Technology Division, Economic Research Service, U.S. Department of Agriculture, Room 508, 1301 New York Avenue, NW., Washington, DC 20005-4788. Also see...

Ethanol: Economic and Policy Tradeoffs, AER-585. U.S. Dept. Agr., Econ. Res. Serv., Apr. 1988.

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