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IMPACTS OF FUEL ALCOHOL PRODUCTION FROM CORN ON LAND USE: A SURVEY

by

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Introduction

It is the purpose of this study to identify the effects on use of land that might be expected should ethanol production from grains become a viable and significant user of grains, and hence cropland. In a sense, changes in the demand for land as a result of ethanol production would be derived from changes in the demand for grains.

Two Scenarios

As an aid for analysis, we first establish two prototypical scenarios under which the land use impacts of ethanol production may evolve. One scenario is more likely to occur than the other, but discussions of the impacts of both scenarios surface throughout this study.

The first scenario hinges on the development of an ethanol production process that is technically and economically efficient at a scale small enough for a few farmers to cooperate in the development and operation of an ethanol production facility. The production inputs, labor, building capital, management expertise, and the corn feedstock would be supplied by the consortium members. They would also consume most of the output of the facility.

For reasons of technical simplicity, the small scale enterprise would employ dry milling technology (U.S. Department of Energy, 1980) rather than the more complex and costly wet milling process. The primary outputs of a dry milling ethanol production plant are wet distiller's grains (stillage) and ethanol. The carbon dioxide co-product is unlikely to be captured for sale by a small ethanol producer. The ethanol could be burned straight in properly modified engines, or if devoid of water ("dry") could be combined with gasoline (usually in a 1:9 mixture) to form gasohol. As a first priority, the ethanol or gasohol would be used to fuel the farm vehicle fleets and the other needs of consortium members. As a second priority, it would be sold to users outside the consortium. Most assuredly, some of the product would be marketed outside the consortium, since most feasible plants would produce too much ethanol for local, on-farm use.

The second scenario assumes that large scale, off-farm ethanol production will dominate the fuel alcohol industry. Farm capital, labor, and management would not be involved directly in ethanol production under this assumption. Farmers would supply the corn feedstock and would therefore be affected indirectly. Much of the large scale production capacity would utilize wet milling technology. This process allows for production of a wide variety of co-products: corn starch, sweeteners, oil, gluten meal and feed, distiller's grains, and carbon dioxide in addition to ethanol. (Starch, sweeteners, and ethanol compete for the starch portion of the corn.) Large scale plants are also able to engage in the more efficient continuous fermentation process, instead of the less efficient batch process (Krohe, 1981).

The Archer Daniels Midland Co. (ADM) of Decatur, Illinois, one of the world's largest grain processing firms, represents the type of large scale ethanol production facility envisioned under the second scenario. In May of 1978, ADM added an ethanol distilling plant to its existing wet corn milling plant at Decatur. The plant was capable of producing 15,000 gallons a day of 200 proof ethanol for gasoline blending. Since then capacity has steadily increased, and now stands at more than 150,000 gallons per day, or more than 50 million gallons per year.

The combination of outputs and by-products produced under the second scenario by the more efficient plants, such as those of ADM, is more complex than those produced under the first scenario. ADM calculates that every 56-pound bushel of corn that passes through its plant yields 1.7 pounds of corn oil, 3 pounds of corn gluten meal, which is 60 percent protein and used by poultry feeders as a feed supplement, 14.5 pounds of corn gluten feed, which is 21 percent protein, 15 pounds of carbon dioxide, and at least 2.5 gallons of 200 proof ethanol.

The large scale production prototype is distinct for our purposes because it draws its feedstocks (assumed to be corn) from regular grain markets. Hence, the impacts on land use are indirect, responding to price signals, rather than the direct impacts associated with the small scale consortium arrangement.

These two scenarios typify the likely range of development of an ethanol production industry. We are interested in investigating potential impacts on land use flowing from these two scenarios. One would not expect either scenario to develop exactly as discussed here. Nor are the two scenarios mutually exclusive.

Classification of Impacts

We will discuss the impacts on land use under three headings: Land Availability, Crop Shifting, and Farm Structure Implication. With regard to land availability, our focus is on expansion of the current land base and the use of acres involved in the government's set aside program to accomodate added grain demand stemming from ethanol production. Concerns about crop shifting center on the displacement of crops not utilized for fuel alcohol by crops that can be so used. Corn is the feedstock crop and soybeans are the non-feedstock receiving most attention. Farm structure becomes a concern when the size, location, and ownership of the plants that make up the ethanol production industry are considered. The impacts of ethanol production on farm structure will be determined by the type of ethanol industry that might evolve, that is whether scenario one or scenario two occurs.

Land Availability

To illustrate the possible new demands that could be placed on agricultural lands by the eventuality of energy production, consider the ethanol production targets posed in 1979 in U.S. Senate Bill 1308. This bill was not passed, however, it does give a sense of the production targets favored by proponents of gasohol. The U.S. Energy Security Act of 1980 (P.L. 96-294) calls for fuel alcohol to meet at least 10 percent of U.S. gasoline use by 1990. At 1980 use rates, this would imply the nearly inconceivable amount of 10 billion gallons of fuel alcohol annually. This conforms to the more extreme goal of Senate Bill 1308.

Title VIII of Senate Bill 1308 would have required a 5 percent alcohol blend in all motor fuels by 1985 and 10 percent by 1990. To meet the 1985 and the 1990 requirements, 2 billion bushels and 4 billion bushels of corn would have been directed to alcohol production for the respective years. Net use would have been about 1.2 and 2.4 billion bushels, respectively, because about 2/5 of this corn would be recovered in high-protein livestock feed supplements that substitute for whole grains otherwise used for animal nutrition (Vollmar, 1980). With the 1981 national average corn production yield just slightly over 100 bushels per acre, the net land requirements for corn production in 1985 would have been approximately 11 million acres and, for 1990, it would have been approximately 23 million acres. The entire 1981 U.S. corn crop was about 8.2 billion bushels. Just over 80 million acres were planted in corn.

Recent estimates by Hauser and Braden (1982) place ethanol production at 75 million gallons in 1981, 155 million gallons in 1982, and 233 million gallons in 1983. Thirty million bushels of corn were required for the 1981 output. At average yields, this corn could be grown on slightly under 300,000 acres. To produce the 155 million gallons of ethanol projected for 1982, with the same average yields, approximately 62 million bushels of corn would have been required from about 600,000 acres. The 233 million gallons estimated for 1983 would require 930,000 acres. These figures indicate ethanol's present importance in corn markets. The far higher levels of output set in Senate Bill 1308 represent 15 to 30 times 1981 corn usage. Is there land available to meet such ethanol production goals, and if so, what will be the costs of attaining the projected goals?

Competition for Land

Raup (1980) included energy production in his list of the five main competitors for land. The four other so-called competitors are highways, reservoirs, urbanization, and recreation. The expansion of urbanizing areas and the growth of agricultural exports have already accentuated the demands being placed on the U.S. land base. Strong export demand in the 1970's contributed to increases in farmland prices to levels that interfered with the orderly succession in ownership and control of land resources. These elements in the pattern of competition for land are exacerbated by the added demands to produce grain alcohol. It is clear that larger acreages of land will be involved. "This adds an intriguing, but largely incommensurable element of concern over competition for land." (Raup, 1980, p. 43)

In terms of area and approximate magnitudes, 32 percent of the 2,264 million acres of land in the U.S. is forested, 26 percent is pasture and range, 21 percent is cropland, 8 percent is devoted to "special uses," which include urban, transport, recreation, wildlife, farmsteads, and various public installations, and the remaining 13 percent is in other lands of low agricultural potential like swamps and deserts (Raup, 1980). See Table 1. Although some problems exist with categorizing land-use over time, it is clear that the area in cropland in the U.S. has been about the same since 1910. The area used for cropland in 1978 (368 million acres) was identical with the acreage in 1920-21. Some of the stability indicated by these figures is negated by certain qualitative shifts, such as the enormous changes that have taken place in land use intensity (Raup, 1980), but such changes are beyond the scope of this paper.

As mentioned earlier, land extensive energy forms, including coal strip-mining, are relatively new entrants in the competition for land compared to roads, reservoirs, residences, and recreation. Among these, the potential for reduced food production capacity is by far greatest in the use of grains to produce motor fuel.

Land available for biomass feedstock production for the purposes of this paper, can be limited to cropland capable of corn production. As an alcohol feedstock, corn has several significant advantages over other biomass forms, such as sugar cane, sweet sorghum, and cattails. Advantages include the facts that a large fraction of the total energy content of the corn plant is in its grains; corn is relatively dry when harvested; methods

Table 1--Land Use Categories

Category	Area (Mil. Ac.)	Percent of Total
Forest	724.48	32
Pasture and Range	588.64	26
Cropland	475.44	21
Special Uses	181.12	8
Other	294.32	13

Source: Raup, 1980, p. 44

of production, harvesting, storage, and transport are well developed; and production is geographically concentrated in the Corn Belt (Raup, 1980). Furthermore, the by-products of corn-based ethanol production are higher in protein and, thus, higher in value than the by-products from other feed-stocks.

Near term projections place corn inputs to ethanol production at about nearly 100 million bushels. It seems unlikely that ethanol production will exceed 1.25 billion gallons annually (500 million bushels) in the 1980's. It should be noted again that a significant amount of non-ethanol corn use will be offset by high protein livestock feed by-products. However, even 1.25 billion gallons of annual output would consume the yields of only about 6 percent of the acreage planted to corn in 1980, at average yields.

The land from which corn is taken for ethanol production can come from three sources: land presently used to grow crops, set aside acres, and land not presently cropped. The USDA estimates 44 million acres in adequate rainfall areas of the country could be converted from non-crop uses if "needed" for crop production. Very high crop prices would be required to generate large scale conversions, in which case ethanol would be a high priced fuel and demand for it could drop. Approximately 24 million cropland acres were set aside in 1978, 6.1 million were diverted from corn production. These totals were relatively large compared to other recent years. There were negligible set asides of corn acreages in 1980 and 1981. Assuming no downward yield bias on set aside lands (Dovring, 1979), potential corn production from the 6.1 million acres would have been about 600 million bushels. This exceeds our estimates of maximum use for ethanol production in this decade, even without offsets for byproducts. However, these acres were presumably reintroduced to harvesting in 1981, when set asides were negligible, so is not a new source of the corn we suggested earlier would have to be allocated to ethanol production. Finally, acreage shifts from other crops (especially soybeans) to corn could account for some of the inputs to ethanol production.

Overall, land availability to grow feedstocks does not appear to constrain ethanol production at forseeable levels of output. It is most useful to view ethanol feedstock demands and affecting overall and relative crop prices. Land use decisions would follow these price signals, perhaps causing some net shift to corn, drawing some non-cropland into planting, and reducing acreages that might otherwise be set aside.

Price and Crop Shifting Impacts

The second major objective of this paper is to assess the crop shifting that may follow relative price changes of crops due to ethanol production. The price impacts discussed here are limited to corn and soybeans in order to simplify the presentation. Sorghum, small grains, and other oil seed crops could also be affected.

For the purposes of determining the price and crop shifting impacts of ethanol production, three studies have been reviewed and their methods and conclusions have been integrated. The first study is based on a "rule of thumb" using the elasticity of demand. Two other studies are simulation models of the corn and soybean sectors.

As a "rule of thumb," a 1 percent change in the supply of a crop will result in about a 2 percent change in the price in the opposite direction if all other factors remain constant. For example, a 5 percent reduction in corn supply will result in a 10 percent increase in the price per bushel if other supply and demand factors don't change. Using this example, $2.50 per bushel corn would then increase to about $2.75 a bushel.

A 250 million gallon a year ethanol industry using corn at the rate of .38 bushel per gallon of production would require 95 million bushels of corn per year. This would be about 1.3 percent of 1979 production. If we assume it is merely removed from aggregate supplies, causing an upward shift in the supply curve, the effect would be a corn price increase of about $0.03 per bushel. There would be about a 5 percent increase in high protein feedstuff supplies and this would result in about a 10 cents per bushel decrease in soybean prices (Vollmar, 1980, p. 76).

Using the same "rule of thumb" and assuming the use of 500 million bushels of corn for ethanol production, a research study for the year 1977 (Vollmar, 1980, p. 76), when U.S. corn production was 6 billion bushels, shows results as follows: 1) a 15 percent increase in corn prices or about 30 to 35 cents per bushel and 2) a 13 cents per gallon increase in the cost of ethanol. Note again, however, that as the demand for corn increased for ethanol production and price increases result, this also means that the corn input for ethanol production has a higher price and increases the per gallon price of ethanol. Use of corn for ethanol might drop accordingly, reducing the price impact.

It was also indicated in the study that the total annual supply of high protein animal feed in 1977 was about 22 million tons, of which distiller's dried grains were less than 2 percent. Soybean meal dominated the supply with about 14 million tons. However, if another 4 to 5 million tons of distiller's grains were added to the 22 million tons supply, with less than offsetting decreases in whole corn feeds, soybean meal prices could drop substantially, perhaps 20 to 25 percent. This would reduce soybean prices at the farm level 50 to 75 cents per bushel (Vollmar, 1980, p. 77).

If corn prices increase and soybean prices decrease, some acreage shift would be expected from soybeans to corn. Furthermore, long run demand is somewhat more elastic than short run demand, so the price impacts of a net reduction in corn supply would be moderated by changes in demand. It should also be remembered that a <u>net</u> subtraction of 500 million bushels of corn supply would require over 800 million bushels be used in ethanol production due to the feed by-products. Such a scenario presently seems quite unlikely.

In a second study, Meekhof, Gill, and Tyner (1980) used FEEDSIM, a simulation model of the corn and soybean sector, to evaluate and compare rates of ethanol production from corn with a base situation in which no ethanol was used. The model allows long-term adjustments to take place. Three alternative sets of additional demand for corn because of increased ethanol production were analyzed:

-Case I--conservative level of ethanol production in 1980/81 and a moderate rate of growth in successive years;

-Case II--conservative level of initial production but accelerated rate of growth, approximates expanded ethanol production capacity for 1980/81 through 1982/83;

-Case III--high level of ethanol production in 1980/81 and accelerated growth.

At the time the study was written, U.S. grain exports to the Soviet Union were suspended. For this reason, the model was simulated once under the assumption of a continuation of the export suspension and once under the assumption that the export suspension would be lifted. The suspension was lifted early in 1981. However, prices and exports have not regained pre-embargo levels. Therefore, we emphasize the results under the embargo assumption, while only occasionally referring to post-embargo results (Meekhof, Gill, and Tyner, 1980, pp. 19-20).

In all three cases, the supply and use of corn and soybeans were altered by the increased demand for corn resulting from expansion of ethanol production. For 1979/80 through 1984/85, average corn prices over the five year period were 2.3, 4.9, and 6 percent higher than base levels for cases I, II, and III, respectively (see Table 2). These price levels correspond to average annual increases in corn demand for ethanol conversion of 256.6, 383.1, and 530.8 million bushels for cases I, II, and III, respectively. Because of responses in other demands for corn, such as the domestic, exports, and stock demand, total demand did not increase by these levels. For all three cases, demand for corn for use in ethanol production increased, and the differences in price levels rose through time. The corn price under case III was as much as 12.3 percent higher than base levels for the later years (Meekhof, Gill, and Tyner, 1980, p. 20).

Prices

As the demand for corn in ethanol production increased, soybean prices declined from base levels. The lower prices were largely due to the impact of soybean demand of increased supplies of DDG. From each bushel of corn used in ethanol production an amount of DDG comparable in feed value to 0.19 bushel of soybeans is yielded. However, DDG substitution of soybean meal is offset by the impact of high corn prices on soybean demand. Over the period of analysis, the average annual soybean prices declined less than 2 percent. See Table 3. The percentage decreases in soybean prices remained in the 2

Table 2--Corn Supply and Use Under Base Case and Alternative Ethanol Production Rates, Export Suspension, 1979/80-84/85

Corn	1979/80	1980/81	1981/82	1982/83	1983/84	1984/85	Average
				Million Acres			
Area Planted:							
Base	80.0	88.8	90.3	87.2	87.7	87.0	86.8
Case I	80.0	88.8	91.4	89.1	90.4	89.9	88.3
Case II	80.0	88.8	91.4	89.1	91.6	93.2	89.0
Case III	80.0	88.8	93.3	90.5	94.8	93.8	90.2
				Million Bushels			
Production:							
Base	7,768	7,690	7,836	7,790	7,951	8,039	7,846
Case I	7,768	7,690	7,891	7,895	8,096	8,206	7,924
Case II	7,768	7,690	7,891	7,895	8,160	8,376	7,963
Case III	7,768	7,690	7.985	7,973	8,319	8,408	8,024
Domestic Demand:							
Base	4,955	5,120	5,316	5,398	5,460	5,554	5,301
Case I	4,955	5,161	5,423	5,566	5,701	5,925	5,455
Case II	4,955	5,161	5,423	5,613	5,940	6,260	5,559
Case III	4,955	5,235	5,538	5,846	6,073	6,248	5,649
				Dollars			
Price:							
Base	2.36	2.30	2.27	2.43	2.56	2.76	2.45
Case I	2.36	2.34	2.34	2.54	2.69	2.94	2.53
Case II	2.36	2.34	2.34	2.59	2.81	2.89	2.56
Case III	2.36	2.41	2.40	2.73	2.87	2.93	2.62

Source: Meekhof, Gill, and Tyner, 1980, p. 21

Table 3--Soybean Supply and Use Under Base Case and Three Ethanol Production Rates, Export Suspension, 1979/80-84/85

Soybeans	1979/80	1980/81	1981/82	1982/83	1983/84	1984/85	Average
				Million Acres			
Area Planted:							
Base	71.6	68.8	68.1	69.5	69.2	69.6	69.5
Case I	71.6	68.8	67.6	68.6	68.1	68.2	68.8
Case II	71.6	68.8	67.6	68.6	67.4	66.6	68.4
Case III	71.6	68.8	66.6	68.0	65.8	66.3	67.8
				Million Bushels			
Production:							
Base	2,271	2,151	2,158	2,226	2,246	2,283	2,222
Case I	2,271	2,151	2,143	2,201	2,211	2,244	2,203
Case II	2,271	2,151	2,143	2,201	2,193	2,194	2,192
Case III	2,271	2,151	2,115	2,182	2,243	2,186	2,175
Domestic Demand:							
Base	1,186	1,261	1,288	1,321	1,338	1,367	1,294
Case I	1,186	1,252	1,265	1,285	1,288	1,295	1,262
Case II	1,186	1,252	1,265	1,275	1,244	1,242	1,244
Case III	1,186	1,236	1,238	1,228	1,211	1,236	1,223
				Dollars			
Price:							
Base	6.14	5.79	6.08	6.44	6.90	7.45	6.47
Case I	6.14	5.76	6.04	6.40	6.83	7.27	6.41
Case II	6.14	5.76	6.04	6.36	6.67	7.11	6.35
Case III	6.14	5.72	6.04	6.27	6.74	7.23	6.36

Source: Meekhof, Gill, and Tyner, 1980, p. 22

percent range even though 117, 146, and 146 million bushels of DDG were produced in 1982/83-84/85 under case III (Meekhof, Gill, and Tyner, 1980, p. 20).

When the demand for corn increases, the relationship between corn and soybean prices changes. As simulated in the model, the ratio of soybean price to corn price generally held between 2.6 and 2.7 under the case of no ethanol production. See Table 4. As a guide, the soybean/corn price ratio for an actual four year period from 1977 through 1980 was 2.7. The proximity of the ratios indicate that the simulation under the base conditions closely resembles actual conditions. In the last two years of the analysis for base conditions, relative soybean and corn prices indicated a potential shift to soybean acreage. For the same years under case III, the most ambitious ethanol production scenario, the soybean/corn price ratio fell to 2.35 and 2.47. The high levels of corn demand under case III reversed the base case change so that corn acres increase and soybean acres decrease.

Acreage Planted

Acreage planted increased for corn but decreased for soybeans as the demand for corn in ethanol production expanded. However, the increases in corn acreage were larger than the reductions in soybean demand. Over the period of analysis total acreage for corn and soybeans increased by a maximum of 2 million acres under case III. The simulation found a direct relationship between the magnitude of acreage changes and the level of corn demand for ethanol production. For cases I, II, and III, the average increases in corn acreages planted above base levels were 1.5, 2.2, and 3.4 million acres, respectively.

Table 4--Soybean/Corn Price Ratios, 1979/80-84/85

Scenario	1979/80	1980/81	1981/82	1982/83	1983/84	1984/85	Average
				Ratio			
Base	2.60	2.52	2.68	2.65	2.69	2.70	2.64
Case I	2.60	2.46	2.58	2.52	2.54	2.47	2.53
Case II	2.60	2.46	2.58	2.47	2.37	2.46	2.48
Case III	2.60	2.37	2.52	2.30	2.35	2.47	2.43
Actual	2.49	2.32	--	--	--	--	2.67*

Source: Meekhof, Gill, and Tyner, 1980, p. 23

*For four year period 1977-1980.

Corn Production

Corn production increased as the level of ethanol production increased, but not enough to meet the additional corn demand for ethanol production. A less than proportional increase in corn production relative to acreage planted occurred because increased acreages were assumed to give slightly lower average yields.

Soybean Production

Under the three ethanol production scenarios, reductions in soybean production corresponded to the lower acreage planted. The reductions in soybean acreage made production average 47 million bushels less annually with case III than with the base case. This was the largest such reduction for the three scenarios. The 100 million bushel decrease in production from 1983/84-84/85 or about a 5 percent reduction was the maximum decrease over the period analyzed (Meekhof, Gill, Tyner, 1980, p. 23).

Corn Demand

As ethanol production increased, significant changes in the composition and level of total corn demand could be noted. Domestic demand increased in all three cases. However, the absolute increases were less than the corn being allocated to ethanol production during the periods when the largest increases in domestic demand took place.

Soybean Demand

Under all three cases domestic soybean demand decreased slightly because DDG was substituted for soybean meal. However, the reduction was less than the amount of DDG coming into the market.

Summary of Meekhof, Gill, and Tyner Production Scenarios

There were no serious price impacts nor supply and demand imbalances for corn and soybeans at the initial levels and rates of expansion in ethanol production in case I. A maximum of 461.5 million bushels of corn was estimated to be used in ethanol production.

In case II, corn used in ethanol production rose to 615.4 and 679.2 million bushels in 1983/84-84/85. The price increases were particularly acute when the export suspension was removed.

In case III, the initial levels and rates of growth in ethanol production and the corresponding corn demand caused severe imbalances in supply and demand over 1982/83-84/85. Again, the imbalances were acute when the export controls were lifted. Corn prices increased greatly above base case levels when the additional corn demand exceeded 600 million bushels, or when ethanol production reached 1.6 to 2.0 billion gallons. The authors suggested that longer term adjustments in the agricultural economy and especially in the corn and soybean sectors could moderate the price impacts (Meekhof, Gill, Tyner, 1980, p. 27).

The increased demand for corn resulting from ethanol production, as computed by the FEEDSIM model, would alter the supply, demand, and price of corn and soybeans. As demand for corn by ethanol producers increased, total corn and soybean acreages increased. In response to a lower soybean/corn price ratio, it was estimated that corn acreage would grow and soybean acreage would fall. However, the increase in corn supplies were anticipated to be less than that required to satisfy the greater demand for corn for ethanol production. Some of the added demand is met from existing production levels and stocks. The FEEDSIM results also indicated that less than a 2 percent drop in soybean prices would transpire as a result of the increased supplies of DDG even with up to 146 million bushels of DDG being produced.

In the third study, another national agricultural policy simulator, POLYSIM, was used to simulate the impacts of using corn to produce ethanol fuel in the agricultural sector of the U.S. economy (Hertzmark, Flaim, Ray, and Parvin, 1980). The model contained supply and demand relationships for the major U.S. crop and livestock categories. A linear ethanol production growth path was imposed on the model over a five year period, with the final year's production ranging from 200 million gallons per year to 3 billion gallons per year, requiring 80 million and 1,200 million bushels of corn, respectively. As the latter case is exceedingly unlikely, we focus on the cases in which final output ranged from 200 to 1,000 million gallons per year.

Based on estimated 1985 production figures without ethanol production, corn prices increased 4.8 percent under the 1 billion gallon ethanol production alternative. Corn acreage increased by only .7 percent. Soybean prices increased by .4 percent, while soybean acreage decreased by .7 percent under the same scenario. In the final year of the simulation, soybean prices remained nearly constant with reduced supplies offsetting the effects of lower meal prices. By the end of five years, net farm income increased only moderately with ethanol production of up to 1 billion gallons (Hertzmark, Flaim, Ray, and Parvin, 1980, p. 969).

The general conclusions reached in the Hertzmark et al. study are consistent with those of Meekhof, Gill, and Tyner. However, the specific degrees of change in prices and acreage shifts were surprising. As expected, corn prices and corn acreage planted increased as ethanol production increased. At the same time, soybean prices increased slightly as a result of decreased soybean acreage. The more remarkable result was the triflingly small changes in the prices of corn and soybeans up to the 2 billion gallon production level.

Comparison of Studies

Results of the Meekhof, Gill, and Tyner study reveal a somewhat greater impact of price and acreage changes than did the Hertzmark et al. study. Even though the magnitude of the shifts varied, their direction of change was consistent.

From each study it can be concluded that ethanol production up to the 2 billion gallon level will not result in serious dislocations in the agricultural sector. This conclusion includes land use. Added corn demand is met mainly from existing production levels plus crop shifting. However, beyond this level of alcohol production the price and acreage shifting outcomes may be significantly greater and beyond acceptable levels in the current food and agricultural policy context.

The Effects of Ethanol Production on Farm Structure

As important as farm structure may be, it is not an easily defined concept. Its definition involves several components. Those found to be pertinent in a discussion of the effects of ethanol production on farm structure include:

-How resources are organized into farming units.

-The size, management, and operation of those resources.

-The degree of freedom to make business decisions, and the degree of risks borne by the operator.

-The manner in which the firm procures its inputs and markets its products.

-The ease of entry into farming as an occupation.

For the most part, society desires public and private policies that tend to promote the idea of the "family farm structure." Although loosely and imprecisely used, the term usually means a relatively large number of modestly sized farms, each operated by a family unit perhaps employing a few nonfamily laborors, but with the husbandry and management decisions made by the operator and the family and the inputs purchased and products sold in open, easily accessible, competitive markets. This may be the national ideal, but the well-known trend is in the direction of fewer and larger farms. In the following section we will discuss the effects of ethanol production on the components of farm structure mentioned above. To begin this section, we note some of the energy-related decisions made at the farm level that affect structure and also some of the structural impacts of specific trends. Also, some structural implications emanating from the two scenarios discussed earlier will be presented.

Potential Impacts of Ethanol Production on the Labor Input

One of the major inputs in the small scale ethanol production scenario is labor. Ideally, it was thought that some amount of under-utilized farm labor could be employed by the on-farm production process. This labor would have a lower-than-market cost due to its ties to the farm consortium and related seasonal underemployment. Labor might also be hired from outside the consortium of farmers. A problem with hiring labor from outside the consortium is that it has been envisioned that labor and management expertise would be embodied in the same individual to reduce costs. Since a high degree of technical competency is required to operate a motor fuel grade ethanol producing plant, employment of a second technically competent laborer would increase the cost of production and lessen the degree of self-sufficiency.

This concept of a labor-subsidized production is highly debatable and has little credibility with most economists. Most ongoing operations and operations coming on-line in the near future plan to employ wage labor.

Impact on Livestock Production

Some of the most far-reaching ramifications of small scale ethanol production arise from the utilization of the distiller's grain. From every bushel of corn with a 13 percent moisture content can be derived approximately 2.5 gallons of ethanol and 16.5 pounds of distiller's grains. This high protein animal feed supplement is suitable for inclusion in the rations of cattle and hogs. However, the distiller's grains are wet. Unless dried, they must be fed within two or three days to avoid spoilage. Drying is possible, but expensive. Given these limitations, livestock must be fed in the vicinity of the ethanol production, if the wet feed is to be consumed. By all assessments, the distiller's grains must be consumed to achieve economic efficiency in ethanol production via the dry-milling process. Such a requirement could encourage expansion of the cattle feedlot industry in the central Corn Belt.

Under the large scale ethanol production scenario, it is not necessary that livestock feedlots be located close to the production facility. Most large scale producers are wet millers and able to produce sweeteners, starch, and oils in addition to ethanol and distiller's grains. They have the capability to dry the byproduct feed grains, so that spoilage is not a problem and shipping is feasible.

Regional Corn Price Impacts from Ethanol Production

The first step in the chain of responses that would impact land use under either scenario would be an increase in the demand for corn as a result of its increased usage as a feedstock for ethanol production. The increased demand for corn would beget higher corn prices and an increase in corn production.

Evidence of regional price impacts from a large ethanol production facility is limited. However, one would expect that where the added demand for corn is met from nearby suppliers, price differentials would arise based on the proximity to the ethanol plant as compared to other outlets for grain.

A large ethanol plant would act in direct competition with other corn users such as local elevators, livestock feeders, and other corn processing firms for the supply of corn in the marketing area. In the short run, to attract the desired quantities of the commodity, the ethanol facility may be required to offer a slightly higher price for the corn than its local competition. In the longer run, prices should equilibrate across the market at a slightly higher level due to added demand. Some smaller capacity elevators in the close vicinity of a new plant may be forced out of business if they are not able to attract adequate supplies through price competition. The fear exists among producers that they may eventually lose local markets and become dependent on one large user of their commodity for price setting.

Higher Farmland Prices

Higher crop prices resulting from the increased demand will be capitalized into the value of farmland. Since the economic value of land can be considered equal to the sum of its future land rents discounted back to the present, an increase in corn price, hence an increase in the net returns to land, would increase the value of the land. It would be noted that this does not imply absolute increases in value. It simply causes values to be higher than they would be in the absence of ethanol production.

Higher valued farmland has structural implications. The higher value land benefits current owners of land. This increase in the current owners' net worth would better enable them to outbid new farmers when other parcels of land are put on the market and to afford capital investments. This is in addition to the already higher price that the seller would expect. This phenomenon could be expected to exacerbate the structural trend toward fewer and larger farms.

Summary

The conclusions of the four price and crop shifting impact studies reviewed in this paper are all generally in agreement that one could expect the increased demand for corn due to increased ethanol production to pull up the price of corn. Given a period for adjustment, new land would come into production and some degree of crop shifting will take place on the current agricultural land base between corn and soybeans. Land rents and values would be higher than they otherwise would be.

For available cropland acres to be increased through land improvements, agricultural price/costs relationships will have to improve beyond those found in the mid 1970's, which were the most favorable in recent decades. At that most favorable period for price/costs relationships in agriculture, producers still preferred to bid up the value of land in current production, rather than invest in land improvements to increase production. This leads to the conclusion that most of the foreseeable demand for grain to produce fuel will be met from the present cropland base, including acreages occasionally committed to set aside programs.

If land prices are forced up by increased ethanol production, certain barriers to entry into agricultural production will be manifested. Increasing land prices benefit the current owners of land most directly. Such circumstances will not diminish the prevailing structural trend of larger and fewer farms.

These will be the direction of the impacts on land use induced by an increasing ethanol production industry. However, the degree of severity of these impacts can only be projected when it is known for certain just how large the ethanol production industry will become. Certain impacts have been estimated in this paper assuming an ethanol industry of 200 million gallons a year to 1.25 billion gallons per year. The actual rate of growth of the ethanol industry will probably be determined by factors exogenous to the industry rather than endogenous at this point in the industry's evolution. The price of competing fuels, imported OPEC crude oil, in particular, is the predominant exogenous factor. Government policies also play a key role.

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