CROPS FOR FOOD OR FUEL: AN ESTIMATE OF THE TRADEOFF

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In the next few years, major expansion of the production of ethanol from grain could take place. With current technology and government subsidies, ethanol is economically competitive for use as an automotive fuel. The limiting factor to growth likely will be plant capacity. Projections indicate that annual production capacity could reach two billion gallons in several years (Tyner, and Meekhof, Gill and Tyner). Production of two billion gallons would use 770 million bushels of corn--equivalent to the corn production of Nebraska in recent years.

While this means higher prices to corn producers, there is a concern about the global food implications. Lester Brown argues that there no longer is excess food production capacity in the United States, and that the U.S. decision to expand the use of cropland for fuel will impair the wellbeing of the world's poor.

A central research issue in the food-fuel debate (and the focus of this paper) is, "How much will the production of ethanol increase the world price of grain?" Two recent studies examine the impact of U.S. ethanol production on corn and soybean prices, trade, farm revenue, etc. Both use simulation models to trace the impact of additional ethanol production over the next several years (Hertzmark, *et. al.*, and Meekhof, Tyner and Holland). They show increased corn prices, decreased volume of crop exports, but increased value of exports. They disagree on whether soybean prices would rise or fall, and neither mentions food grain prices. The research reported in this paper

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differs from the above research in two ways; emphasis is on the international market, and a long-run partial equilibrium trade model is used. The equilibrium model does not trace the path of adjustment as does the simulation approach, but it does give an estimate of the total impact of a disequilibrating factor, such as the extra ethanol production.

RESEARCH APPROACH

An economic model for addressing the food-fuel tradeoff question could be very complex. In this paper the use of corn to produce ethanol is examined. A by-product of the distilling process is distillers dried grain; a substitute for soybean meal. Thus, the ethanol production process directly affects the markets for corn, soybeans, soybean meal and soybean oil. Because of competition for land and other inputs, ethanol production also impacts the food grain and fiber markets. Since these commodities are traded in international markets, the model should also include supply, demand, domestic policy and trade components for all other major producing and consuming countries. One can glean from all this, four categories of economic relationships that are most important in determining the food-fuel trade-off:

(1) the elasticity of supply of cropland in the United States and other major crop producing countries,

(2) the elasticity of demand for grains and soybeans in the United States and other major consuming countries,

(3) trade and domestic policy restrictions, and

(4) cross-price elasticities among major crops in both supply and demand.

The approach used in this paper is to make a simplifying assumption in order to remove (4) from the analysis. That greatly simplifies the analysis and allows one to emphasize the other three sets of relationships listed above.

Over the range of prices and quantities examined in this paper, it is assumed that the relative prices of the grains and soybeans will not change in the long run even though there might be a shift in demand for feed, food, meal or oil. Constant relative prices among feed grains (corn, oats, sorghum and barley) are assumed in many studies. Feed grains tend to be near-perfect substitutes for each other in livestock feed. If ethanol demand drove up the price of corn, the prices of the other three feed grains would be expected to eventually increase by the same proportion because of their substitution for corn in feed. Production characteristics of corn and soybeans in the Corn Belt tend to hold constant the price ratio between those two crops. It takes a soybean price of about 2.5 times the corn price per bushel to equate profits per acre. The supply of land for which this is true is large enough to hold international prices of the two crops about at that ratio even after the demand for either one shifts. The case for a constant wheat-feed grains price ratio is somewhat more tenuous. There are many acres that could easily shift between wheat and barley or oats in the Northern Plains, or between wheat and sorghum in the Southern Plains if the price ratios changed only slightly. On the demand side, wheat is used as a feed in some parts of the world, and some feed grains are used for food. These substitution potentials should hold the wheat-feed grains price ratio nearly constant over the intermediate run, even though the demand for either might shift.

Model and Assumptions

Because of the grain price ratio assumption discussed above, a very simple model may be used to approximate the impact of ethanol production on world grain prices. The model follows the form described by Thompson. It is a single-commodity, two-region, long run, partial equilibrium model. The single commodity analyzed is the aggregate of coarse grains, wheat and soybeans, referred to as "grain" in this report. Rice is omitted because relatively little is traded and its substitution possibilities with other grains are relatively less.

The world is divided into two regions, the United States and the Rest-of-the-World (ROW) since the focus of this study is on the impact of ethanol production on grain availability in those two regions. The impact on specific foreign countries would require a more detailed study. Some inferences, however, can be drawn from the results for individual countries.

"Price" is a quantity-weighted index number that represents the value of an aggregate ton of "grain" on the world market. It represents the price of "grain" to U.S. producers and consumers, as well as the price to producers and consumers in the other region, ROW. Transportation charges and exchange rates are eliminated to simplify the analysis. Implied is the assumption that a change in the level of ethanol production in the United States will not cause a significant change in transportation costs or exchange rates. If no change is expected, those factors may be ignored. The assumption of constant exchange rates is less realistic if ethanol production substantially changes the value of U.S. grain exports or oil imports.

This is a long-run adjustment model which implies that (1) changes in stocks levels are not relevant, and (2) supply is a function of current-period price. Thus, the model is specified as:[1/]

[1] $UQ_S = 131.77P^{.2}$

[2] $UQ_D = 780.29P^{-.3}$

[3] $RQ_S = 632. + 115.85P^{.2}$

[4] $RQ_D = 781. + 1{,}053.13P^{-.29}$

[5] $UX_S = UQ_S - UQ_D$

[6] $RX_D = RQ_D - RQ_S$

[7] $UX_S = RX_D$

1/ All quantity units are million metric tons, referred to hereafter as "million tons."

where: UQ_S = U.S. supply of "grain,"

UQ_D = U.S. demand for "grain,"

RQ_S = Rest-of-the-World supply of "grain,"

RQ_D = Rest-of-the-World demand for "grain,"

UX_S = U.S. excess supply of "grain,"

RX_D = Rest-of-the-World excess demand for "grain," and

P = world trade price.

Specification of the parameters in the seven equations is a two-step process. The first step is to define a base period that may reasonably be assumed to be in long-run equilibrium. The selected base period is the average of the three marketing years 1978/79 to 1980/81. Data describing the base period are in table 1. The second step is to obtain estimates of elasticities for the supply and demand equations, [1] to [4]. Given the base period data, the elasticities, and a price (assumed to be 100 for the base period), all constants in the 7-equation model can be specified. Thus, the "BASE" solution to the model is a price of 100, and the quantities produced, consumed and traded as specified in table 1.

The price elasticities specified in equations [1] to [4] are based upon reports by McCalla, Bredahl, et. al., Jabara, and Bishop. The elasticity of supply of "grain" with respect to domestic price is assumed to be 0.2 in all countries. Since the United States has no "grain" price barriers to trade, the elasticity of supply with respect to world price is 0.2 in equation [1]. An examination of the major producing regions in the rest of the world indicates that about 70 percent of "grain" production is not responsive at all to changes in world price. Various trade barriers in those countries cut the link between the domestic and world price. The ROW supply equation, [3], thus contains a constant term representing nonresponsive production and a second term, with a price power coefficient of 0.2, representing production in countries that respond to changes in world price.

Table 1--Crop production, use, trade, and area harvested, U.S., Rest-of-World, and World, selected crops, annual average over 1978/79 to 1980/81

Item	United States	Rest-of-World	World
	Million tons		
Soybeans			
Production	54	30	84
Domestic use 1/ 2/	25	59	84
Exports (net) 1/	29	-29	--
Wheat			
Production	57	377	434
Domestic use 2/	20	414	434
Exports (net)	37	-37	--
Coarse grains			
Production	220	516	736
Domestic use 2/	151	585	736
Exports (net)	69	-69	--
Grains and soybeans ("Grains")			
Production	331	923	1,254
Domestic use 2/	196	1,058	1,254
Exports (net)	135	-135	--
	Million hectares		
Area harvested of:			
Soybeans	27.3	22.2	49.5
Wheat	25.6	204.9	230.5
Coarse grains	42.1	298.5	340.6
TOTAL ("Grains")	95.0	525.6	620.6

1/ Includes meal and oil.

2/ Adjusted to absorb the net stock change over the three years.

Source: USDA, World Agricultural Supply and Demand Estimates, WASDE-111, January 15, 1981.

Elasticity of demand for soybeans, wheat and coarse grains with respect to domestic price are assumed to be -0.4, -0.2, and -0.3, respectively, for all countries. When weighted by the quantities consumed, the aggregate elasticity of U.S. domestic demand becomes -0.30 (see equation [2]). An analysis of the remainder of the major consuming countries, by commodity, indicates that about three fourths of consumption does not respond to world price--represented by the constant term in [4]. The weighted average elasticity for world price-responsive consumption in the ROW is -0.29.

The Analysis

The 7-equation model is used to obtain two solutions: the "BASE" solution and the "ETHANOL" solution. The BASE solution presented graphically in figure 1 corresponds to the base period data in table 1. Excess supply of the United States and excess demand of the ROW are in equilibrium at a price of 100 with 135 million tons traded (point A in the right graph).

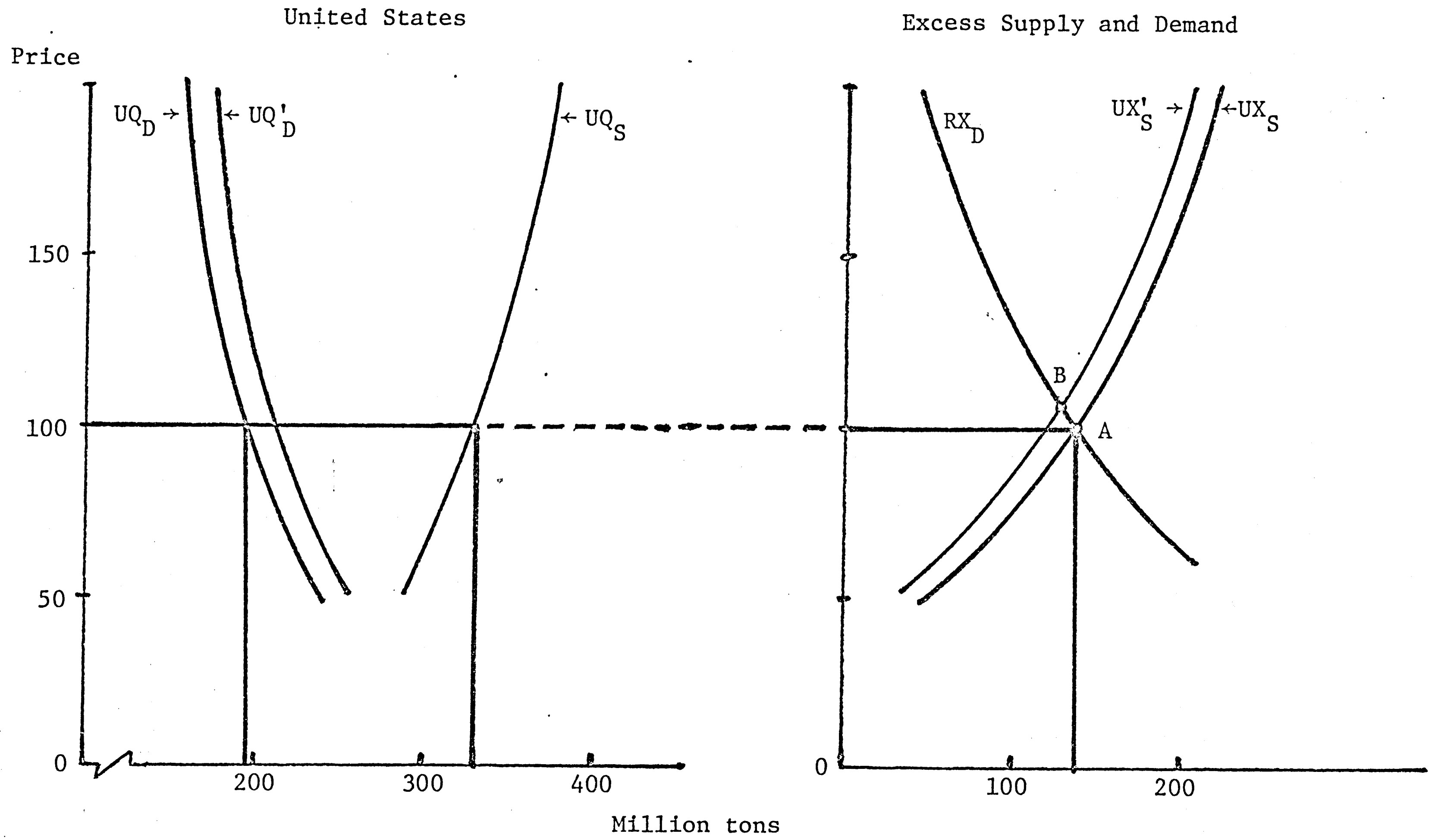
The ETHANOL solution assumes that the United States produces an additional two billion gallons of ethanol from corn per year in the base period using a dry milling process. It takes 16 million tons of "grain" to produce the ethanol, taking into account the feed value of the by-product.[2/] Thus, the U.S. demand for "grains" is increased by 16 million tons. For the ETHANOL solution, equations [2], [5], and [7] are modified:

[2]' $UQ_D' = UQ_D + 16$ [7]' $UX_S' = RX_D$

[5]' $UX_S' = UQ_S - UQ_D'$

[2/] It is assumed that one ton of corn yields 101 gallons of ethanol and .31 tons of distillers dried grain. The latter substitutes for soybean meal at the rate of 1.63 lbs. DDG for one lb. meal (Tyner). Thus, 19.8 million tons of corn are used in the distilling process but 3.8 million tons of soybean meal equivalent are produced. The net production in "grains" is 19.8 - 3.8 = 16 million tons.

Figure 1--Supply, demand and trade of "grain," two scenarios



RESULTS

The revised U.S. demand curve and excess supply curve are shown in figure 1. The increased U.S. demand shifts U.S. excess demand to the left. A new equilibrium trade volume and world price is obtained at point B in the right graph. Though the quantity change seems small, keep in mind that this additional ethanol production would represent only two percent of U.S. gasoline consumption.

Impact on Price

The production of an additional two billion gallons of ethanol increases the world price of "grain" 6.3 percent--equivalent to about 24 cents per bushel of wheat on the farm in the U.S. (1979 dollars). In the context of this model, the respective prices of corn, wheat, soybeans, and the other grains would all increase 6.3 percent (table 2). With corn being the major feedstock, the initial impact of the ethanol production would be to increase corn price well over six percent. But other feeds would substitute for corn in consumption, and cropland would shift from soybeans and other crops to corn. If the elasticities of substitution among crops in consumption and production were very elastic as hypothesized, the crop sector would reach a new equilibrium with all crop prices higher than in the previous equilibrium, and with all price ratios nearly the same as before the increase in ethanol production. Given the shape of the supply and demand curves, price would increase about 3.2 percent for each billion gallons produced over the range of 0 to 4 billion gallons of ethanol.

Impact upon United States

The 16 million tons of "grain" used for ethanol would come from three U.S. market adjustments: "grain" production would increase by 4.0 million tons, consumption would decrease 3.6 million tons and exports would drop 8.4

Table 2--Annual production, use, and trade of "grain" under two scenarios, base period, United States and ROW

Item	BASE	Additional ethanol production	Difference (2) - (1)
	(1)	(2)	(3)
		Value units per ton	
World price[1/]	100.0	106.3	6.3
United States		Million tons	
Production	331.0	335.0	4.0
Ethanol use	0.0	16.0	16.0
Other domestic use	196.0	192.4	-3.6
Exports	135.0	126.6	-8.4
ROW			
Production	923.0	926.6	3.6
Domestic use	1,058.0	1,053.2	4.8
Imports	135.0	126.6	-8.4
World			
Production	1,254	1,261.6	7.6
Use (other than new ethanol)	1,254	1,245.6	8.4
United States		Billion value units[2/]	
Production	33.1	35.6	2.5
Other domestic use	19.6	20.5	0.9
Exports	13.5	13.4	-0.1
ROW			
Production	92.3	98.5	6.2
Domestic use	105.8	111.9	6.1

[1/] The price index of 100 is equivalent to a farm price of corn of about $2.50 per bushel in 1979/80.

[2/] Quantities multiplied by the price index per ton.

million tons (table 3). The additional production would require about four million crop acres--an increase of less than two percent. The increased production coupled with the higher price would increase "grain" revenue to farmers 7.6 percent. U.S. users of "grain" would use about two percent less at the higher price, but the total bill for that reduced consumption would be about four percent more.

Though the quantity of "grain" exports decreases as a result of the ethanol production, the value of exports remains nearly constant. The price elasticity of the excess demand curve, given the assumptions of this model, is -1.02 at a price of 100. The increase in world price nearly offsets the decrease in quantity exported.

Impact upon Other Countries

The rest-of-the-world would also feel the impact of the ethanol production in the U.S. The higher world price would increase their "grain" production 3.6 million tons and reduce consumption 4.8 million tons in order to offset the 8.4 million ton reduction in imports from the U.S. The additional production would come mainly from other exporters of wheat, coarse grains and soybeans. The consumption adjustment is only 0.5 percent of total use in the ROW, but it would be concentrated in those countries where domestic prices were linked to world prices. Countries with fixed domestic prices (i.e., not linked to world price) would have no consumption adjustment, but they would have to pay a higher import bill--6.3 percent higher.

For the world as a whole, slightly less than half of the 16 million tons of grain used for ethanol production would come from increased production. The rest would come from reduced consumption (table 3).

Table 3--Source of the additional 16 million tons of "grain"

Source	U.S.	ROW	World
	Million tons		
Increased production	4.0	3.6	7.6
Reduced use	3.6	4.8	8.4
Reduced exports	8.4	-8.4	0.0
TOTAL	16.0	0.0	16.0

Impact upon World Welfare

Who would gain and who would lose from the ethanol production? Let's ignore the value of the ethanol and examine only producers and consumers of grains and soybeans. U.S. producers would gain. So would producers in those countries where their government policy allowed the world price changes to reach the farm--mainly exporters such as Canada, Australia, South Africa, Brazil, and Argentina. U.S. consumers and consumers in countries where market prices reflected world prices would lose. They would pay more for "grain" and get less. Both producers and consumers would lose in countries where grain prices were fixed. Their welfare from the direct production and consumption of "grain" would not change, but their government would pay a higher import bill to maintain consumption. Thus, national wealth would be reduced. Most of the world's population fits into the latter category. Thus, there would be a redistribution of income with producers in a few countries experiencing a significant welfare gain, while all other people were experiencing a small welfare loss. Finally, it is interesting to note that foreign producers would, in aggregate, receive more of the gain than U.S. producers.

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