Fuel Ethanol Subsidies and Farm Price Support: Boon or Boondoggle?

by

Bruce Gardner

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Department of Agricultural and Resource Economics

The University of Maryland, College Park

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Bruce Gardner
Department of Agricultural and Resource Economics
2200 University of Maryland
College Park, MD 20742-5535, USA
bgardner@arec.umd.edu

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An interesting category of regulatory policies are those which subsidize or mandate private-sector use of a particular industry's output. Agricultural economists have not given such demand-inducing regulation nearly the attention they have given price supports, but industry groups have taken these policies seriously. For example, the National Corn Growers have treated regulations promoting ethanol use as a top priority for their members. Some general press accounts of the issue, however, emphasize instead the benefits of such regulations to ethanol manufacturers.[1]

This paper analyzes the determinants of gains to farmers from demand-inducing regulations. It considers under what condition, if any, a dollar spent on ethanol subsidies is as effective for farmers' economic interests as a dollar spent on commodity programs. It also considers whether ethanol subsidies may be preferable from a general welfare viewpoint. The approach used to analyze this issue is also extended to public investment in research on ethanol and other "new uses" of agricultural products.

The Model

To analyze the issue in as simple a framework as possible that still permits a meaningful assessment, consider the following supply and demand model. Corn is used either for traditional feed/food uses or as raw material for ethanol. Ethanol is produced using corn, with 1 bushel of corn yielding 2.5 gallons of ethanol and aggregated plant, equipment and other inputs in a Leontief (fixed

[1]For example, Robert Novak, "Ethanol Outrage," Washington Post, Oct. 5, 1995; James Bovard, "Dole, Gringrich, and the Big Ethanol Boondoggle," Wall Street Journal, Nov. 2, 1995.

proportions) production function. In addition to ethanol, corn yields feed by-products. Both plant-and-equipment and corn are specific factors to the ethanol industry.

This model can be depicted graphically as shown in figure 1, a combination of the standard derived demand model for joint products with an excess supply model in which the raw material has a second (feed) use. The top panel shows the demand for industrial corn products in two vertically additive components: ethanol and by-products. The horizontal axis can be measured in gallons of ethanol, tons of by-products, or bushels of corn, since the products are generated in fixed proportions from corn. Since corn is the common raw material for both industrial products, bushels of corn is the quantity unit used in the diagram. This means that the prices of ethanol and by-products are quoted in terms of dollars paid for the product that results from 1 bushel of corn, e.g., if ethanol's price is $1 per gallon we depict a $2.50 price because we obtain $2.50 worth of ethanol from each bushel of corn at the conversion rate of 2.5 gallons per bushel. The total demand curve, D_T, is the vertical sum of D_y, the demand for ethanol, and the demand for by-products, D_z. The derived industrial demand for corn, shown in the lower panel as D_I, is obtained as the vertical distance between D_T and S_N the supply of non-corn inputs in ethanol production (rental value of ethanol plant, energy, labor). Industrial demand is however only part of the demand for corn. We add (horizontally) the quantity of corn purchased for feed and export at each price to obtain D_C, the total demand for corn. The model is closed by adding the supply function of corn, S_C.

Three policies are considered in this model. First, a target price and deficiency payment program. As illustrated in figure 1, this program generates payments of t per bushel of corn to achieve a price to producers of $\overline{P}_C$. This causes larger output and a lower market price of corn. The effect in the ethanol market is to reduce the price of both ethanol and by-products and to increase the price of non-corn inputs in ethanol, principally the rent earned on ethanol plants. The gains to corn growers growers and ethanol manufacturers are the single-hatched areas in the lower and upper panels, respectively. Social or deadweight losses are the double-hatched area.

A second commodity program is acreage controls which restrict production such that S_C crosses D_C at the market price level $\overline{P}_C$. This would cause the prices of both ethanol and by-products to rise and a reduction in rents to ethanol plants (none of this shown in diagram).

The third policy is an ethanol subsidy. To show this graphically we first sketch the excess supply curve of corn for industrial purposes from the (horizontal) difference between S_C and $D_C - D_I$, the demand for corn for feed and export, at each price. This curve is shown as S_I in figure 1. What we know is that S_I crosses D_I at P_C, and has a flatter slope than S_C. This curve, the marginal cost of corn for ethanol, is added (vertically) to S_N in the upper panel to obtain the derived supply of industrial products from corn, S_T. The ethanol subsidy, s, is then analyzed as a wedge between S_T and D_T, analogous to the payment, t, in the corn market under policy 1. The ethanol subsidy as sketched generates the same gains to ethanol manufacturers as did the deficiency payment, t, by construction. Corn producers also gain from the ethanol subsidy, since the increased use of ethanol increases the derived demand for corn. But the price gain, shown where the quantity induced by s cuts the supply curve S_I, is less than was achieved with the deficiency payment.

The graphical analysis thus indicates that both corn producers and ethanol manufacturers will gain from either an ethanol subsidy or corn deficiency payments, but corn producers gain relatively more from deficiency payments and ethanol producers gain relatively more from an ethanol subsidy. However, acreage controls make farmers better off and ethanol producers worse off. What we actually have in U.S. policy is a blend of all three policies. The policy issues then turn on adjusting all three instruments (t, s, and acreage controls) at the margins. In order to analyze these issues more fully, and test their sensitivity to parameter values (such as elasticities of supply and demand) one must express the model algebraically.

The behavioral equations, in price-dependent constant elasticity form, are:

(1) Ethanol demand:

$$P_y = ay^{n_y}$$

(2) By-product demand

$$P_z = bz^{n_z}$$

(3) Supply of non-corn ethanol inputs

$$P_w = cw^{e_w}$$

(4) Demand for non-ethanol uses of corn

$$P_x = dx_2^{n_x}$$

(5) Supply of corn

$$P_x = h(x_1 + x_2)^{e_x}$$

where y, z, w, x_1, and x_2 are quantities, P's are prices, n's are inverse demand elasticities, e's are inverse supply elasticities, and a to h are constants.

The industrial demand for corn used in ethanol is not independent of the preceding equations. It is derived easily in inverse form:

(6) $$P_x = P_y + P_z - P_w$$

$$= ay^{n_y} + bz^{n_z} - cw^{e_w}$$

As in figure 1, all prices are expressed in terms of bushels of corn. Thus, P_y is the dollar value of the ethanol from a bushel of corn, and P_z is the price of non-corn processing services per bushel of corn. This approach simplifies the quantities also since they are all measured in bushels of corn:

(7) $\quad y = z = w = x_1$

After using (7) to eliminate y, z, and w, we are left with the six equations (1) to (6) in six unknowns, P_y, P_z, P_w, P_x, x_1 and x_2. Therefore, with well-behaved (monotonic, continuous, negatively sloped demand and positively sloped supply) functions, a unique equilibrium exists.

The system can be simplified by substitution using (7) and (6) to obtain:

(8) $$P_x = ax_1^{n_y} + bx_1^{n_2} \quad cx_1^{e_w} + s$$

(9) $$P_x = h(x_1 + [P_x^{1/n_2}/d])^{e_x} - t$$

i.e., two equations in two variables, P_x and x_1, and all of the 10 parameters (constants and elasticities) of equations (1) to (5). To carry out comparative statics of policy alternatives, the following steps are taken. First, we add an ethanol subsidy, s, to the derived demand equation (8). The subsidy has the effect of a reduction in the cost of manufacturing ethanol (which is why s is added while $cx_1^{e_w}$ is subtracted). Second, we subtract deficiency payments per bushel, t, from equation (9). P_x is thus the market price of corn, while producers get $P_x + t$ per bushel. Instruments s and t have different effects because equation (8) contains only x_1, while (9) contains $x_1 + x_2$. Third, we model production control by making h a policy instrument rather than a fixed parameter.

To analyze the effects of a change in the ethanol subsidy, differentiate (8) and (9) with respect to s:

(10) $$\frac{dP_x}{ds} = \left(n_y a x_1^{n_y\ 1} + n_z b x_1^{n_z\ 1} \quad e_w c x_1^{e_w\ 1} \right) \frac{dx_1}{ds} + 1$$

(11) $$\frac{dP_x}{ds} = e_x h \left(x_1 + \left[P_x^{1/n_2} / d\right]\right)^{e_x - 1} \left(\frac{dx_1}{ds} + P_x^{\frac{1}{n_2} - 1} / [n_2 d] \frac{dP_x}{ds} \right)$$

There is no straightforward way to solve these nonlinear equations for dP_x/ds, the effect of s on P_x. Therefore a numerical solution algorithm was developed for equations (8) and (9) that, using any parameter values (n's, e's, and constants), finds equilibrium P_x, x_1, and x_2 for any s or t.

An analytical solution is straightforward when equations (1) to (5) are linear (or linearized as a first-order approximation to nonlinear functions). The behavioral equations are then:

(1N) $P_y = a_0 + a_1 y$

(2N) $P_z = b_0 + b_1 z$

(3N) $P_w = c_0 + c_1 w$

(4N) $P_x = d_0 + d_1 x_2$

(5N) $P_x = h_0 + h_1(x_1 + x_2)$

Equation (8), the inverse derived demand for corn in ethanol, is now

(8N) $P_x = (a_0 + b_0 - c_0) + (a_1 + b_1 - c_1)x_1 + s$

Equation (9N), obtained by solving (4N) for x_2 and substituting for x_2 in equation (5N), is

(9N) $$x_1 = -\frac{h_0}{h_1} + \frac{d_0}{d_1} + \left(\frac{1}{h_1} - \frac{1}{d_1}\right) P_x .$$

It is clearer now than in (9) that (9N) is the excess supply of corn available for use in ethanol.

Solving (8N) and (9N) simultaneously for x_1,

(12) $$x_1 = \frac{(a_0 + b_0 - c_0 + s)(d_1 - h_1) - h_0 d_1 + d_0 h_1 + d_1 t}{(a_1 + b_1 - c_1)(h_1 - d_1) + d_1 h_1}$$

To see the effect of a change in the ethanol subsidy, s, differentiate (12) with respect to s to obtain

(13) $$\frac{dx_1}{ds} = \frac{1}{\dfrac{1}{1/h_1 - 1/d_1} - (a_1 + b_1 - c_1)}$$

and

(14) $$\frac{dP_x}{ds} = \frac{dP_x}{dX}\frac{dX}{ds} + \frac{ds}{ds} = \frac{(a_l + b_l - c_l)}{\frac{1}{1/h_l - 1/d_l} - (a_l + b_l - c_l)} + 1$$

where $(a_l + b_l - c_l)$ is the slope of the inverse derived demand curve (< 0) and $(1/h_l - 1/d_l)$ is the slope of the excess supply curve (> 0).

[In the case where the derived demand and excess supply functions of corn for industrial uses is linear in logs, equations (13) and (14) become:

(13N) $$\frac{Ex}{Es} = \frac{1}{1/\varepsilon_I - 1/\eta_I}, \quad \frac{EP_x}{Es} = \frac{1}{1 - \varepsilon_I/\eta_I}$$

where E is the percentage change operator, ε_I is the excess supply elasticity of corn for industrial uses and η_I is the derived demand elasticity for corn in industrial uses. Note that if either $\varepsilon_I = 0$, or $\eta_I = -\infty$, i.e., corn for ethanol is fixed in supply or perfectly elastic in demand, P_x rises by the full amount of the subsidy. This means farms get all the gains.]

The effect of s on the price of non-corn inputs (a proxy for the profits of Archer-Daniels-Midlands) is

(15) $$\frac{dP_w}{ds} = \frac{dx}{ds} \bullet \frac{dP_w}{dx} = \frac{dx}{ds} \bullet \frac{dP_w}{w} = \frac{c_l}{e - n}$$

where $e = (1/h_l - 1/d_l)^{-1}$ and $n = a_l + b_l - c_l$. Similarly,

(16) $$\frac{dP_y}{ds} = \frac{a_l}{e - n}, \quad \frac{dP_z}{ds} = \frac{b_l}{e - n}.$$

Thus,

(17) $$\frac{d(P_y + P_z + P_w + P_x)}{ds} = \frac{-a_l - b_l + c_l + e}{e - n} = \frac{-n + e}{e - n} = 1$$

Since $-dP_y$ and $-dP_z$ are proportional to the gains to consumers of ethanol and by-products, and P_w and P_x the gains of ethanol producers and corn producers, equation (17) just says that all the gains add up to ds, the change in the subsidy. The interest groups share in the gains as $-a_1$/ds for ethanol buyers, $-b_1$/ds for by-product buyers, c/ds for ethanol producers, and e/ds for corn producers. However, corn producers gain not only on the corn they produce for ethanol, but also on the corn used for other purposes, and the domestic buyers of this (feed) corn bear a loss equal to this gain (minus gains on exported corn). So corn producers' gain is e/ds/α, where α is the share of corn that goes into ethanol.

<u>Effects of an Ethanol Subsidy Compared to Deficiency Payments</u>

The key parameters are the elasticities from equations (1) to (5), or the corresponding slopes in (1N) to (5N). Unfortunately, we do not have econometric estimates of most of them. The corn supply elasticity has generally been estimated to be quite small, 0.2 to 0.5. The elasticity of demand for corn in feed and export uses has been estimated in the -.5 to -.8 range. The elasticity of demand for ethanol has not been estimated econometrically, but a relatively elastic -2.0 to -5.0 has been suggested on the grounds that quite good substitutes exist.

The elasticity of demand for by-products, mainly corn gluten feed and meal, depends heavily on international trade policy of both the U.S. and other countries. There has been a market for these products in Europe because of access provisions negotiated between the U.S. and EU, which would imply highly elastic demand. Under the 1994 GATT agreement this access will be more limited and less valuable, but the demand will still be fairly elastic because the by-product quantities are small relative to the EU and U.S. feed market as a whole ¥¥ doubling ethanol use would generate feed by-products whose tonnage is only about 2 percent of the combined U.S. and EU feed supply. Therefore, a relatively high elasticity of demand, -3 to -10, is plausible.

The elasticity of supply of non-corn inputs into ethanol is especially conjectural because these inputs are an aggregate of disparate goods and services. Energy and labor are essentially perfectly elastic in supply to the ethanol industry. But ethanol plant and equipment is essentially fixed in the short run, and is likely to be inelastic in supply in the intermediate run. We will consider a range of intermediate elasticities, from 1 to 4, for the aggregate supply of these inputs. It is particularly important to conduct a sensitivity analysis of this parameter, since it is the key determinant of the gains and losses to ethanol manufacturers resulting from alternative policies.

Consider first simulations using the (geometric) means of the parameter ranges just given.[2] With no policies in place, the farm price of corn is $2.00 per bushel. Production is 7.5 billion bushels, of which 0.2 billion is used for ethanol and 7.3 billion for all other purposes. The price of ethanol is $2.50 per bushel of corn ($1.00 per gallon of ethanol). The price of by-products is $1.60 per bushel (9 cents per pound of by-product), and the cost of non-corn inputs in ethanol production is $2.10 per bushel of corn converted. Note that the value of corn plus non-corn inputs (2.00 + 2.10) equals the value of ethanol plus by-products (2.50 + 1.60). The value of ethanol produced is (0.2 H 2.5) $0.5 billion and the value of the corn crop is (7.5 H 2.0) $15 billion.

Introducing a subsidy of 50 cents per gallon of ethanol produced ($1.25 per bushel of corn used) generates the following results. (See Appendix for details of calculations, using the linear model of equations (1N) to (5N).) Ethanol production increases from 200 to 293 million bushels of corn-equivalent (732 million gallons), at a cost to the government of $367 million in subsidies. The producer price of ethanol (including subsidy) rises 27 percent, and ethanol producers gain economic rents of $121 million (24 percent of the no-policy revenue). The price of corn rises 1.3 percent, and corn producers gain $191 million (1.3 percent of no-policy revenue). Table 1 shows the redistributional details. Corn producers benefit even more than ethanol plant owners from the

[2]The geometric mean is the square root of the product of the endpoints of the range, e.g., the geometric mean of 1 and 4 is 2. This is relevant for elasticities since sensitivity analysis makes most sense by, say, halving and doubling the mean value.

ethanol subsidy. It therefore seems reasonable for corn producers to favor an ethanol subsidy as much or more than ethanol manufacturers do.

Next consider a deficiency payment program that costs the same to taxpayers as the ethanol subsidy. This requires a target price of $2.03 per bushel and a payment of 5 cents per bushel, with the market price of corn falling to $1.98. This policy also generates a gain to ethanol manufacturers, since it reduces the market price of the raw material. But the gain to ethanol manufacturers is only about $1 million. The gain to farmers is $243 million. Therefore farmers would prefer to have limited government funds spent on deficiency payments.

<u>Possibility of ethanol subsidy being preferable</u>. The question arises whether farmers' preference for the deficiency payment approach is robust to parameter assumptions that have been made. From equations (15) to (17), the biggest gainers are those with the least elastic supply or demand functions. So to have the ethanol subsidy work best for farmers, we should have the demand for ethanol and by-products be as elastic as possible, and the excess supply of corn for ethanol as inelastic as possible. Let the elasticities of demand for ethanol and its by-products be -5 and -10, respectively, and let the elasticity of supply of non-corn inputs in ethanol be 4.0. To obtain a less elastic supply of corn to ethanol production, let the elasticity of supply of corn remain at 1/3, but the elasticity of demand for non-ethanol uses of corn be -0.4. These assumptions constitute case 2, under which the results of a 50-cent per gallon ethanol subsidy and equivalent-costing deficiency payment program are shown in lines 3 and 4 of Table 1. In this case farmers and ethanol producers both prefer the ethanol subsidy to a deficiency payment program.

Table 1. Gains and Losses from Ethanol Subsidy and Alternative Policies

Policy:[1]	Gains to (1) Corn growers	(2) Ethanol producers	(3) Domestic consumer	(4) Taxpayers	Transfer efficiency (1) + (2)/(3) + (4)
	- - - - - - - - - million $	- - - - - - - - - - -			
1. ethanol subsidy (base case)	191	121	6	-367	.86
2. deficiency payment (base case)	243	1	90	-366	.88
3. ethanol subsidy (case 2)	553	156	-250	-498	.95
4. deficiency payment (case 2)	287	3	163	-509	.84
5. ethanol mandate (base case)	191	121	-361	0	.86
6. acreage reduction program plus def. payment	193	0	0	-243	.79
7. ARP plus mandate plus deficiency payment	311	121	-361	-120	.90

[1]Policies and market assumptions described in text.

The main reason for the change is the less elastic demand for corn in non-ethanol feed and export uses. Consumer interests in these programs, which have so far been neglected, have four components: fuel ethanol users, ethanol by-product users, feed users, and buyers of U.S. corn exports. The second and fourth sets of buyers are foreigners, and their gains or losses are excluded from the (nationalistic) calculations of table 1. With a deficiency payment program, the market price of corn falls and buyers of all corn products gain. The ethanol subsidy, however, bids corn away from non-ethanol uses to ethanol production, causing the market price of corn to rise (line 1), the gains of ethanol buyers and the losses of feed buyers about cancel out. But with less elastic feed demand in case 2 the ethanol subsidy drives up the price of corn more sharply, and this is both helpful to corn producers and bad for (nonsubsidized) corn users. Thus, the reason why the ethanol subsidy is better for both farmers and ethanol producers than deficiency payments that cost taxpayers the same amount is that the deficiency payment shares the gains with consumers, while under the ethanol subsidy consumers add to the pot which is redistributed to producers.[3]

In this context, perhaps the best measure of overall redistributional effectiveness is the joint gains of corn and ethanol producers divided by the joint losses of taxpayers and consumers. This is the measure of "transfer efficiency" shown in the right-hand column of table 1. With respect to this measure the deficiency payment wins in the base case, but the ethanol subsidy wins in case 2.

Politics and Ethanol Mandates

Even assuming the base case, which was said to be most plausible, reflects the true state of affairs, farmers may be right to focus on ethanol policy. One reason is political: farmers can get lobbying assistance from ethanol producers for the ethanol subsidy. Indeed the ethanol industry can

[3]It's essentially a price discrimination scheme where the elastic-demand ethanol buyers are offered a low price relative to the inelastic-demand feed buyers. This depends on greatly differing elasticities, which we have in case 2 but not in the base case.

be expected to do the heavy political lifting while farmers can save their political capital for other efforts.

A second reason for farmers' enthusiasm about ethanol is that a slight variation on the ethanol subsidy, namely ethanol mandates under the Clean Air Act Amendments of 1990, has further advantages. As implemented so far, these mandates require 30% of oxygenated fuels, needed for areas that haven't met clean air standards, to be ethanol-based. Analytically, it is apparent from Figure 1 that the corn-price effects and producer gains caused by an ethanol subsidy of s can be exactly duplicated by a mandate that adds quantity M to the demand for ethanol. The only difference is that the government subsidy cost is replaced by increased consumer expenditures of the same amount. Thus, there exists a level of mandated ethanol use that generates the results shown in line 5 of table 1. Corn growers could well find this policy attainable when the deficiency payment of line 2 is not politically feasible because of government budget stringency.

Acreage Controls

Consider supply control through an Acreage Reduction Program (ARP) as currently carried out in U.S. grains policy. The key features of the program are: (1) in order to be eligible for the target-price guarantee, a farmer must reduce acreage planted by x percent; (2) the ARP acreage cannot be planted to another cash crop, and (3) the base for payments is frozen, i.e., cannot be increased by increasing the farmer's acreage or yield. This creates a perfectly inelastic supply function with respect to market prices, for prices below the target price, at the level of production established by base acreage and yield minus the ARP percentages (assuming all farms participate).

Suppose this policy is superimposed on the deficiency payment program of figure 1, in such a way that output is at the no-program level, x_0 in figure 1. The guarantee of $\overline{P}_c$ now leaves output unchanged, so all market prices are unchanged, including the industrial products of corn. Payments are not a lump-sum transfer with no deadweight loss because of the idled acreage. This cost to farmers can't be shown in the diagram without further assumptions (e.g., identical farmers, each of whom has homogenous-quality land), but the cost can be calculated as the rental value of idled land. Under "base case" conditions idled land would have to equal 1 percent of the crop's acreage, assuming you have to enroll 2 acres to get output reduced by the output of 1 average acre (50% "slippage"). With land rental accounting for 1/3 of all costs, or 67 cents per bushel of corn in the base case, the cost to farmers of the 1 percent set-aside is $50 million. This has to be subtracted from deficiency payments to get the farmers' net gain, as shown in line 6 of table 1.

Now consider adding an ethanol mandate, with a more modest deficiency payment of $120 million. This policy is the best of all so far considered for farmers and ethanol producers jointly, and is most efficient in delivering the largest percentage to producers of what taxpayers and consumers give up. (Nonetheless, all the policies have deadweight losses ― the sum of columns (1) to (4) is negative ― so from the point of view of national income the best policy is none of the above.[4])

Environmental Issues

The best policy, in line 7 of Table 1, adds 93 million bushels of corn (232 million gallons of ethanol) to the free-market equilibrium, at a net social cost of $49 million.[5] This cost amounts to 53 cents per gallon of ethanol, or 5.3 cents per gallon of 10-percent ethanol fuel. If this fuel has clean air benefits of more than 5.3 cents per gallon used, then the ethanol subsidy generates a net social gain.

[4]One possibility for a net social gain is if there were monopoly power in ethanol production. Then an ethanol subsidy, properly chosen, could remove the efficiency loss caused by too little ethanol production by the monopolist.

[5]These effects are the same as in the base case, and details of the calculations are in the appendix, where x1 = .2, x1n = .293, and dw = -.049.

[A simpler way of making this calculation, at the margin, is to apply the principle that the marginal deadweight loss caused by a subsidy is just the amount of the subsidy minus (in a second-best situation) the marginal reduction in other distortions. The marginal distortion caused by the subsidy is $1.25 per bushel of corn drawn into ethanol production. The marginal reduction in other distortions is the value of reduced ARP acreage plus environmental (clean air) benefits. By earlier assumptions the marginal value of land is 67 cents per bushel (1/3 of market price). Therefore the net marginal value of growing a bushel of corn on ARP-idled land and using it to produce subsidized ethanol is 67 - 125 = 58 cents per bushel. So we need 58 cents of environment benefits per bushel of corn, or 58/2.5 = 23 cents per gallon of ethanol.]

Investment in Ethanol Technology

There exists an analyzed sum of money, MM, which when invested in research on corn-to-ethanol conversion reduces costs sufficiently to shift the supply curve S_T in Figure 1 downward by the distance s. This will generate exactly the redistributional results of an ethanol subsidy, for example as in line 1 of table 1 for the base case parameter values; except that if MM is less than the cost of the subsidy, this policy is preferable to taxpayers (and ethanol researchers).

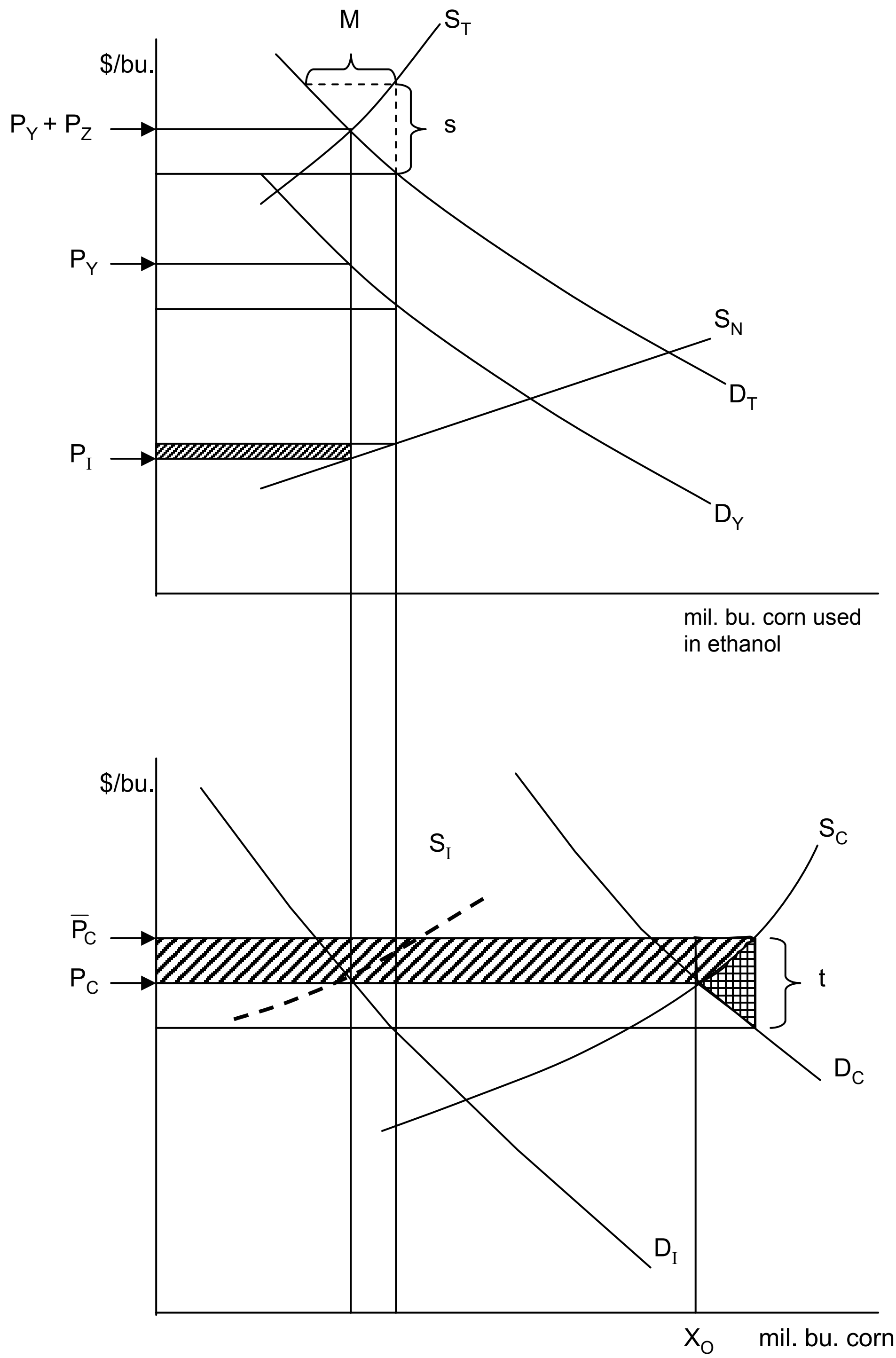

Figure 1. Ethanol and Corn Markets with Deficiency Payments