Munich Personal RePEc Archive

The Welfare Economics of an Excise-Tax Exemption for Biofuels

Harry de Gorter and David R. Just

Cornell University

September 2007

Online at http://mpra.ub.uni-muenchen.de/5151/
MPRA Paper No. 5151, posted 5. October 2007

WP 2007-13
September 2007

Working Paper

Department of Applied Economics and Management
Cornell University, Ithaca, New York 14853-7801 USA

The Welfare Economics of an Excise-Tax Exemption for Biofuels

Harry de Gorter and David R. Just

The Welfare Economics of an Excise-Tax Exemption for Biofuels

Harry de Gorter

and

David R. Just*

17 September 2007

Abstract

A general theory is developed to analyze the efficiency and income distribution effects of a biofuel consumer tax credit and the interaction effects with a price contingent farm subsidy. Using the U.S. ethanol market as a stylized example, ethanol prices rise above the gasoline price by the amount of the tax credit. Corn farmers therefore gain directly while gasoline consumers only gain from any reduction in world oil prices due to the extra ethanol production and domestic oil producers lose. Because increased ethanol production improves the terms of trade in both the export of corn and the import of oil, we determine the optimal tax credit and the conditions affecting it.

Historically, the intercept of the ethanol supply curve is above the gasoline price. Hence, part of the tax credit is redundant and represents 'rectangular' deadweight costs. The tax credit reduces the tax costs of price supports but incurs tax costs itself and increases consumer costs of corn. Price supports eliminate, create, have no effect or have an ambiguous effect on rectangular deadweight costs, depending on whether there is *ex ante* or *ex post* water in the tax credit. There are situations where ethanol production occurs only because of price supports.

A stylized empirical model of the U.S. corn market is calibrated to illustrate the welfare effects of a tax credit. Net social costs of the tax credit averaged $683 million. Rectangular deadweight costs averaged $1,056 mil., more than offsetting the improved terms of trade and reduced price contingent farm subsidies, and representing over 50 percent of the tax cost of the tax credit.

Key words: biofuels, tax exemption, rectangular deadweight costs, price subsidies, welfare economics

JEL: F13, Q17, Q18, Q42

* Associate and Assistant Professor, respectively, Department of Applied Economics and Management, Cornell University. There is no senior authorship assigned as authors are listed strictly in alphabetical order. This is a revised version of a paper presented at the International Workshop on *Economics, Policies and Science of Bioenergy*, Ravello Italy, 26 July 2007.

The Welfare Economics of an Excise-Tax Exemption for Biofuels

1. Introduction

Biofuels have generated a great deal of interest worldwide as a solution to a host of problems, ranging from reducing dependency on oil and tax costs of farm programs to improving farm incomes and environmental quality (Miranowski 2007; Zilberman 2007). Ambitious goals on the use of biofuels are being set in many countries, including developing countries (Jank et al. 2007; Kojima and Johnson 2006, Rajagopal and Zilberman 2007). In addition to grants, guaranteed loans and tax incentives for the production of biofuels, many governments exempt biofuels from consumer excise taxes to help achieve targets on biofuel use.[1] Along with high oil prices, the tax exemption for ethanol facilitated the increase in demand for agricultural commodities in U.S. biofuel production (Tyner 2007).[2] Although ethanol accounted for only 4 percent of transportation fuel consumption and 20 percent of total corn use in 2006, the rapidly expanding production of ethanol has resulted in sharp increases in the price of corn. As well, the increase in resources devoted to corn production has pushed up prices of other commodities that compete with corn for land, are substitutes in demand for corn or use corn as an input (Elobeid et al. 2007). This has a direct adverse effect on the users of these crops, including livestock industries and consumers in developing countries (Runge and Senauer 2007). Meanwhile, increased market prices reduced the tax costs of price contingent farm subsidies.

This paper develops a prototype welfare theoretic framework to analyze the efficiency and income distribution effects of a biofuel consumption tax credit and the interaction effects with price contingent production subsidies. Following Gardner (2003), we analyze the U.S. ethanol tax credit and loan deficiency payments as a stylized example to empirically illustrate the implications of the model. Unlike in Gardner (2003), where the tax credit is modeled as an ethanol production subsidy reducing market prices for ethanol, our model has the tax credit providing an incentive for gasoline blenders to bid up the market price of ethanol above the market price of gasoline by the amount of the tax. Hence, the market price of ethanol and corn are positively related. Gasoline consumers only gain from the reduction in world oil prices due to the extra ethanol production while domestic oil producers lose. Because increased ethanol production improves the terms of trade in both the export of corn and the import of oil, we determine the optimal tax credit and the conditions affecting it.[3]

One bushel of corn produces 2.8 gallons of ethanol so the tax credit translates into a potential \$1.43 per bushel increase in the corn price. Except in times of very high oil prices, the intercept of the ethanol supply curve is above the market price of ethanol that would occur without the tax credit. This means a significant part of the tax credit can be redundant. This 'water' in the tax credit represents 'rectangular' deadweight costs, defined as that part of the cost of the tax credit that is not a transfer to corn producers. Therefore, any terms of trade improvements in the export of corn and import of oil can easily be eliminated.

Using a stylized empirical model of the U.S. corn market to illustrate the potential welfare effects of a tax credit, rectangular deadweight costs averaged \$1,067 mil. from 2001 to 2006.[4] The tax costs of the tax credit averaged \$1,813 mil. This means that more than 50 percent of the tax costs due to the tax credit were rectangular deadweight costs.

Although the tax credit reduces taxpayer costs of price contingent farm subsidies, the net gain in taxpayer monies is ambiguous. Furthermore, tax savings in farm subsidies are replaced by increases in costs to corn consumers and by part of the tax costs of the tax credit. The other part of the tax credit's cost to taxpayers represent rectangular deadweight costs.

The effect of the loan rate on rectangular deadweight costs are to both increase and decrease it (net effect is ambiguous), to eliminate it, to create it, or to have no impact at all. The outcome depends on whether the market price of corn is above or below the price that would prevail without ethanol production, and on whether there is water in the tax credit with the loan rate. There are situations where ethanol production occurs only because of price supports.

This paper is organized as follows. The next section develops the general theoretical model while Section 3 analyzes the interaction effects between the tax credit and price supports. Section 4 presents an algebraic formulation of the general theory while Section 5 presents the empirical results, including the effects of a variable tax credit. The last section provides some concluding remarks.

2. Theoretical Model

A key aspect of analyzing the corn-oil market interface is the equilibrium breakeven price of corn. Figure 1 summarizes estimates by Tyner (2007) and Elobeid et al. (2006) of a linear relationship between the corn and oil price. These estimates of the breakeven curve differ, but the slopes are nearly identical and approximate the logarithmic trend in ethanol prices. Linearity suggests that there are constant returns to scale in ethanol production and that the oil price is invariant to ethanol production.[5] In the analysis to follow, we assume the former but allow for an endogenous oil price in the theory section only. Tyner (2007) also shows that ethanol has an additive value as an oxygenate and octane enhancer. This additive value is assumed to be fixed in our model and is normalized to zero. We also assume ethanol imports to be exogenous as international trade in biofuels has been small (IPC 2006). Except for episodes of very high U.S. ethanol prices, most imports into the United States normally come through a preferential trading arrangement with Caribbean countries and are limited by an import quota.

Denote the U.S. corn supply curve by S_C and total demand for non-ethanol corn by D_{NE} (Figure 2). Their intersection determines the price of corn P_{NE} that occurs with no ethanol production. The excess supply of corn for ethanol production S_E is given in panel (b) of Figure 2. Denote S_d as the domestic supply curve for gasoline. This along with the import supply curve generates a total gasoline supply curve S_F. Since the intercept of the ethanol supply curve is assumed to be above the price of gasoline P_G, the supply curve S_F is of gasoline only. The intersection with the domestic demand for fuel D_F solves for P_G, the market price of gasoline.[6] In this situation, the corn price P_C equals P_{NE} and is not related to oil prices.

Define t as the 51 cent per gallon tax credit to refiners for using ethanol with gasoline. Competition among refiners will ensure that the market price of ethanol will rise and equal $P_G + t$, the price paid by consumers of gasoline. The supply curve for ethanol shifts down by the amount of the tax credit t to S'_E. The new fuel supply curve becomes S'_F such that domestic oil production and imports fall to OG and GH, respectively. The new level of fuel (ethanol and gasoline) consumption is OJ, resulting in gasoline and corn prices of P'_G and P_C, respectively. The corn price is now equal to the gasoline price plus the tax credit of \$1.43 per bushel.[7]

Gasoline consumers only gain from the consumption tax credit through the reduction in world oil prices due to the extra ethanol production. The tax credit raises the price to corn producers and non-ethanol corn consumers (an equal production subsidy and consumption tax) by $P_C - P_G$, which is less than the tax credit t because of (a) possible water in the tax credit equal to P_{NE} - P_G (the difference between the intercept of the ethanol supply curve and initial price of gasoline); and (b) the reduction in fuel prices due to ethanol production of P'_G - P_G. The tax credit therefore reduces gasoline use by the distance HI in Figure 2 and increases fuel consumption by IJ.

Non-ethanol consumers of corn transfer area *a* to corn producers while taxpayers transfer area $b + c + d$ plus the hatched and cross-hatched areas.[8] The hatched area represents rectangular deadweight costs of the tax credit while the cross-hatched area represents the transfer from taxpayers to fuel consumers due to the decline in fuel prices resulting from increased ethanol production. Corn producer surplus increases by area $a + b + c$ and the deadweight costs of overproduction is given by area *d*.

Water in the tax credit varies year to year as it depends critically on both P_{NE} (market conditions in the corn market) and the price of gasoline (market conditions in the oil market). For example, a large increase in the price of oil will reduce water in the tax credit and may even eliminate it. If so, the rectangular deadweight costs disappear and become part of the transfer to corn farmers. Denote *w* as the water in the tax credit: $w = P_{NE} - P_G$. If oil prices are low enough, water can equal the entire tax credit. Note also that $w = t - (P_C - P_{NE}) - (P_G - P'_G)$. Oil prices have to increase by more than the water, *w*, before all water in the tax credit *t* is squeezed out.

Figure 3 presents a more detailed explanation of the various costs and benefits of the tax credit. Panel (a) shows domestic oil production to be OG, oil imports to be GH and ethanol consumption to be HJ (letters corresponding to that in Figure 2). Domestic oil producers lose revenues of area $e + f + g$ while the international terms of trade improvement in oil imports is area $f + g + h$.[9] The terms of trade improvement from increased ethanol production in oil prices is captured by domestic consumers and is given by area $i + j + k$ (corresponding to the cross hatched area in panel (a) of Figure 2). The gain by domestic gasoline consumers from taxpayers is due to the international terms of trade effect for oil. The gain in consumer surplus is the sum of all areas denoted in panel (a) of Figure 3 less area *k* (the deadweight costs of over-consumption) while the international gains from trade in the oil market is offset by area *f* (the deadweight costs of underproduction of domestic oil).

The detailed breakdown of welfare effects in the corn market is depicted in panel (b) of Figure 3. Denote the domestic demand for non-ethanol corn by D_d. The transfer to corn producers from domestic non-ethanol corn consumers is area *l* while transfers from importers of U.S. corn is area $n + q$.[10] Deadweight costs of under-consumption is given by area *n*. The cross hatched area is identical to that in panel due to because of increased ethanol production induced by the tax credit that displaces gasoline consumption. Corn producers only get the full benefit of the tax credit *t* if the price of oil is fixed and there is no water in the tax credit. There are four deadweight cost triangles (areas *f* and *k* in Figure 3a; area *n* in Figure 3b and area *d* in Figure 2b). Net U.S. social welfare can be positive with a tax credit because of these two international terms of trade improvements. The U.S. import tariff on ethanol may also improve their terms of trade in world ethanol markets. Adding a foreign excess supply curve of ethanol to the model would allow one to analyze this. Finally, there may be more net social gains if we include the effects of the tax credit subsidy in reducing price contingent subsidies for corn. We take this issue up in the next section.

3. Interaction Effects between a Tax Credit and Price Contingent Farm Subsidies

There are two particularly important issues to analyze: the impact of the tax credit on the tax costs of the loan rate program, and the impact of the loan rate on the tax costs of the tax credit, including that part which is rectangular deadweight costs. The analysis assumes oil prices are exogenous so the market price for corn P_C is determined by the price of gasoline plus the tax credit.[11]

Consider first the case in Figures 4a,b where the observed market price for corn P_C is above P_{NE}, the corn price with no ethanol production. If the tax credit is the only policy in effect, then the taxpayer costs are $t \cdot (Q_C - C_{NE})$ where Q_C is production with the tax credit only and C_{NE} is non-ethanol corn consumption. If the loan rate is the only policy in place, then the tax costs are $(L - P_L) \cdot Q_L$ where L is the loan rate (guaranteed price to producers), Q_L is corn production with the loan rate and P_L is the market price of corn without the tax credit. Tax costs with both the tax credit t and loan rate are L,

(1) $(L - P_C) \cdot Q_L + t \cdot (Q_L - C_{NE})$

The loan rate in this case (Figures 4a,b) has no impact on non-ethanol corn consumption. The first term of equation (1) denotes the tax costs of the deficiency payments independent of the tax credit. We therefore focus on the second term. We know that t can be expressed as,

(2) $t = P_C - P_G = (P_C - P_L) + (P_L - P_G)$

Therefore, the gross tax savings of deficiency payments due to the tax credit is given by,

(3) $(P_C - \text{MAX}[P_L, P_G]) \cdot Q_L$

Let us consider the case of Figure 4a only where $P_L > P_G$. The components of Q_L in equation (3) are given by,

(4) $Q_L = C_{NE} + (Q_C - C_{NE}) + (Q_L - Q_C)$

Using each of the right hand terms of (4) with (3), we can breakdown the different components of the tax savings in deficiency payments due to the tax credit. To begin, part of the tax savings represents increased costs to consumers of corn (both domestic and foreign),

(5) $(P_C - P_L) \cdot C_{NE}$

Another part of the tax costs of the tax credit is independent of the deficiency payment program,

(6) $(P_C - P_L) \cdot (Q_C - C_{NE})$

but some of the tax costs of the tax credit are due to the deficiency program, $(P_C - P_G)\cdot(Q_L - Q_C)$. For now, let us focus only on that part of the loan rate's contribution to the tax costs of the tax credit which cancels with the reduction in tax costs of the loan rate due to the tax credit, namely

(7) $(P_C - P_L)\cdot(Q_L - Q_C)$

The increased costs in equations (5) – (7) exactly cancel the reductions in the tax costs of the deficiency payment program due to the tax credit given by equation (3). However, there are tax costs of the tax credit yet unaccounted for that are above and beyond the tax savings in deficiency payments. These are the tax costs that represent rectangular deadweight costs and are given by,

(8) $(P_L - P_G)\cdot(Q_L - C_{NE})$

Define water in the presence of the loan rate as $w_L = P_L - P_G$ which is always less than the water without a loan rate $w = P_{NE} - P_G$. Because of the water, the shaded area in Figure 4a represents that part of the tax costs of the tax credit that are deadweight costs. The second term in parentheses of equation (8) can be re-written as,

(9) $Q_L - C_{NE} = (Q_C - C_{NE}) + (Q_L - Q_C)$

Using each term in (9) and combining with (8), we can therefore identify two components of the extra tax costs due to the tax credit that are beyond the savings in tax costs of deficiency payments due to the tax credit. The first of these is the rectangular deadweight cost of the tax credit regardless of deficiency payments,

(10) $w_L\cdot(Q_C - C_{NE})$

followed by the rectangular deadweight costs of the tax credit due to the deficiency payment program,

(11) $w_L\cdot(Q_L - Q_C)$

To summarize, the tax savings of the deficiency payment program in equation (3) are offset by increased consumer costs and tax costs of the tax credit policy given in equations (5) – (7) that exclude the additional rectangular deadweight costs described in equations (10) – (11). This is only relevant for the case in Figure 4a. Nevertheless, part of the increased consumer costs in equation (5) is to foreign importers of U.S. corn exports, thereby increasing the U.S. international terms of trade in corn export markets. These terms of trade gains can more than offset the additional rectangular deadweight costs, depending on market parameters. We discuss this further in the empirical section later.

The net savings in total taxpayer costs due to the tax credit is ambiguous in theory and depends on the relative size of $(P_C - P_L)\cdot C_{NE}$ versus $w_L\cdot(Q_L - C_{NE})$. Given that the share of corn used in ethanol production is historically much lower than all other uses of corn, it is likely that the tax credit results in a net savings in tax costs. This may change in the future however as ethanol production increases along with market prices of corn. Nevertheless, the reduced tax costs are more than offset by higher prices to consumers and rectangular deadweight costs.

So far we have shown that part of the existing rectangular deadweight costs is due to deficiency payments. Let us now examine the effect of the deficiency payments on rectangular deadweight costs in general. The loan rate expands output by $Q_L - Q_C$. The rectangular deadweight costs with the tax credit t only are:

$$w\cdot(Q_C - C_{NE})$$

The rectangular deadweight costs with both the tax credit t and loan rate L are:

$$w_L\cdot(Q_L - C_{NE})$$

Hence, rectangular deadweight costs increase by $w_L\cdot(Q_L - Q_C)$ and decrease by $(P_{NE} - P_L)(Q_C - C_{NE})$. The net effect of the loan rate on rectangular deadweight costs is therefore ambiguous.

An exogenous increase in the price of oil will reduce water and increase market price for corn, with the reduced non-ethanol corn consumption diverted to ethanol use. A decrease in the tax credit has exactly the opposite effect. Note that the effects of these exogenous changes in the oil price and tax credit are the same for each of the cases examined in Figures 4-5.

However, the analysis so far assumes water with the loan rate is positive *ex ante* and *ex post*. Figure 4b depicts the case where the initial water, $w = P_{NE} - P_G$, is eliminated with the introduction of the loan rate so the loan rate unambiguously reduces rectangular deadweight costs in this situation. Otherwise, the analysis above in equations (1) – (7) holds for the case depicted in Figure 4b as well.

The analysis so far in Figures 4a,b assumes positive ethanol production with no loan rate. However, this may not be the case as it is possible that the market price of corn P_C is less than P_{NE} as shown in Figures 5a,b.[12] In the case of water in Figure 5a, rectangular deadweight costs before the introduction of the loan rate is zero because water in the tax credit is 100 percent and so there is no ethanol production. After the introduction of the loan rate, the rectangular deadweight costs are $w_L \cdot (Q_L - C_{NE})$. Hence, the loan rate creates rectangular deadweight costs in this case.

In Figure 5b where there is no rectangular deadweight costs, the loan rate has no impact on rectangular deadweight costs.

In summary, the tax credit decreases tax costs of the loan rate but increases consumer costs and incurs rectangular deadweight costs, part of which is due to the loan rate. Meanwhile, the loan rate increases the tax costs of the tax credit, part of which cancels the reduced tax costs of the loan rate. Rectangular deadweight costs are an extra burden of the tax credit. The effect of the loan rate on rectangular deadweight costs are to both increase and decrease it (net effect is ambiguous), to eliminate it, to create it, or to have no impact at all. The outcome strictly depends on which of the four possible initial equilibriums. Thus it is vital to understand the prevailing equilibrium if one is to assess the welfare effects of the tax credit.

4. An Algebraic Formulation of the Welfare Effects of the Tax Credit

Because the tax credit for ethanol can have such disparate effects on welfare and trade, we derive the optimal tax credit for a large country exporter of corn and importer of oil for each of the situations described in Figures 2-5. This serves as an important benchmark to understand how different market parameters determine the social welfare effects of the tax credit policy.

Consider a demand sector represented by the indirect utility function $V(P,Y)$, where P is the vector of prices and Y the level of income. This indirect utility function generates the demand curve for corn, $q^D = -V_{P_1}/V_Y$, and for fuel $q_F^D = -V_{P_2}/V_Y$. The supply sector can be represented by $\pi(P)$ generating the supply curve for corn, $q^S = -\pi_1$, where the subscript 1 denotes the derivative of the first element of P. Likewise, the supply curve for gasoline is given by $q_G^S = -\pi_2$. Additionally, let the foreign demand for corn be given by $q^X = q^X(P)$ and the import supply of gasoline given by q_G^X. Denote the tax credit given to ethanol producers as t, thus $P_c' = P_c + t$. The optimal t solves

$$\max_t V\left(\begin{bmatrix}\tilde{P} & P_g\end{bmatrix}, Y\right) \tag{12}$$

subject to

$$Y = Y_0 - t\left(q^S(\hat{P}) - q^D(\tilde{P}) - q^X(\tilde{P})\right) - \delta q^S + \pi(\hat{P}, P_c),$$

$$q_G^S(P_c) + q_G^X(P_c) + \left(q^S(\hat{P}) - q^D(\tilde{P}) - q^X(\tilde{P})\right) = q_F^D(P_c),$$

where $\hat{P} = \max\{P_c + t, P_{NE}, L\}$ is the producer price for corn, $\tilde{P} = \max\left\{P_c + t, q^{-1D}\left(-\pi_1\left(\hat{P}\right)\right)\right\}$ is the consumer price for corn, $\delta = \max\left\{L - \tilde{P}, 0\right\}$ is the deficiency payment. The variable P_{NE} is defined implicitly as $q^S\left(P_{NE}\right) = q^D\left(P_{NE}\right) + q^X\left(P_{NE}\right)$, L is the loan rate, and $q^{-1D}(.)$ is the inverse of the demand function for corn consumption.

Let η^i be the price elasticity of curve *i*. Define the elasticity of excess supply of ethanol by $\kappa_1 = \eta^S \frac{q^S}{q^X} - \eta^D \frac{q^D}{q^X} - \eta^X$, the elasticity of excess demand for ethanol as $\kappa_2 = \eta_F^D - \eta_G^S \frac{q_G^S}{q_F^D} - \eta_G^X \frac{q_G^X}{q_F^D}$ and define $\kappa_3 = \kappa_1 - \eta^S \frac{q^S}{q^X}$. The corn devoted to ethanol is defined by $E = q^S - q^D - q^X$ and the excess demand for imported gasoline and domestic ethanol fuel is given by $M = q_F^D - q_G^S$. Solving the optimization conditions for (12) (see the appendix for a complete proof), we find:

(i) if $P_L > P_{NE} > L$, then

$$t = \begin{cases} \dfrac{P_c}{(\kappa_1 - 1)}\left[(E - M)\dfrac{\kappa_1}{q_F^D \kappa_2} + 1\right] & \text{if} \quad \left(\dfrac{\kappa_1}{\kappa_1 - 1}\right)\left[\dfrac{E - M}{q_F^D \kappa_2} + 1\right] > \dfrac{P_{NE}}{P_c} \quad \text{(CASE A)} \\ 0 & \text{otherwise} \quad \text{(CASE B)} \end{cases}$$

(ii) if $L > P_{NE} > P_L$, then

$$t = \begin{cases} \dfrac{P_c}{(\kappa_1 - 1)}\left[(E-M)\dfrac{\kappa_1}{q_F^D \kappa_2} + 1\right] & \text{if} \quad \left(\dfrac{\kappa_1}{\kappa_1 - 1}\right)\left[\dfrac{E-M}{q_F^D \kappa_2} + 1\right] > \dfrac{L}{P_c} \quad \text{(CASE A)} \\ \dfrac{P_c}{(\kappa_3 + 1)}\left[(E-M)\dfrac{\kappa_3}{q_F^D \kappa_2} + 1\right] & \text{if} \quad \dfrac{L}{P_c} > \dfrac{1}{(\kappa_3 + 1)}\left[(E-M)\dfrac{\kappa_3}{q_F^D \kappa_2} + \kappa_3 + 2\right] > \dfrac{P_L}{P_c} \quad \text{(CASE C1)} \\ 0 & \text{otherwise} \quad \text{(CASE C2)} \end{cases}$$

The formula defines the parameters that will minimize areas *a* and *d* in Figure 2a and area *n* in Figure 3b while at the same time maximize the area *q*. If the oil price is exogenous, then κ_2 is infinite, leaving only the last term in each case. When the loan rate is not operational (as in CASE A above) the optimal tax credit is then given by $P_C/(\kappa_1 - 1)$. The more inelastic the domestic supply and non-ethanol demand (domestic and foreign) curves are, the higher the optimal tax credit or equivalently, the lower the social costs of the tax credit. In this case, the tax credit has a relatively smaller impact on the amount of corn used for non-ethanol consumption, thus reducing the incidence of the tax. In addition, the higher the share of corn exports relative to supply (weighted by the supply elasticity) and relative to domestic demand (weighted by the domestic non-ethanol demand elasticity), the lower the social cost of the tax credit. In this case corn importers carry the brunt of the corn price increase, the added revenue to domestic producers outweighing the loss to domestic consumers.

Because we assume the oil market absorbs all ethanol at a fixed world oil price, the elasticity of demand for ethanol is not a factor. If the loan rate is operational (CASE C1), then the social cost of the tax credit will no longer depend on the supply of corn as this is fixed at the loan rate. The optimal tax will now only depend on the properties of the domestic and foreign demand for corn, κ_3.

When oil prices are endogenous, then the results are conditioned by $-(E-M)$, or the amount of fuel from foreign oil producers, and k_1/k_2 , the ratio of the elasticities of excess supply and demand of ethanol. The higher the imports of oil, the lower the social cost of the tax credit. In this case, the tax credit allows fuel consumption to substitute ethanol for imported oil, potentially improving the terms of trade (both lowering the imported oil price and raising the corn price for exports). Additionally, the more negative the ratio of elasticities of excess supply and demand for ethanol, the lower the social cost of a tax credit. While the tax credit raises the corn price, the higher elasticity of supply suggests that corn producers can increase production to take advantage of the better terms of trade. Alternatively, the lower (less negative) elasticity of demand for ethanol suggests that domestic consumers of fuel do not adjust their ethanol consumption very much, given the price decrease in fuel. Thus the tax credit will more directly improve the international terms of trade. Table 1 summarizes these results for each of the possible price contingencies described in Figures 2-5 that could affect the social welfare effects of the tax credit.

5. An Empirical Illustration

The basic market parameters calibrated and derived for the U.S. corn market are summarized in Table 2. Annual data are presented for the crop years 2001/02 to 2006/07 for which the simulations were undertaken. Data were obtained from the United States Department of Agriculture (USDA). The supply and demand curves were calibrated assuming a constant elasticity of 0.4, -0.2 and -1.0 for corn supply, domestic demand and export demand, respectively. An estimate of the corn price without ethanol production P_{NE} is first required to determine water in the tax credit (with and without the loan rate). Water is found to be positive in each year. Note that the average water in the tax credit was $1.12/bu with no loan rate and

$0.89/bu with the loan rate. As a result, the tax credit caused ethanol production such that the average price of corn was higher by $0.31/bu, far less than the implied subsidy of $1.43/bu often attributed to the tax credit.[13]

The first three columns in Table 3 show the various sources of deadweight costs with the deadweight cost triangle averaging $179 mil. and $38 mil. due to overproduction and underconsumption of corn, respectively. However, rectangular deadweight costs averaged $1,067 mil. (column [3]) and are slightly lower than if there was no loan rate (column [4]).[14] As described in the theory section, the loan rate has an ambiguous impact on rectangular deadweight costs. Comparing data in column [3] with [4], rectangular deadweight costs were higher without the loan rate in 2001/02 but lower in 2003/04.

Average total tax costs were $3,229 mil. while average transfers from domestic and foreign consumers to corn producers were $2,221 and $633 mil., respectively. Net social welfare was negative in every year, averaging -$683 mil. (column [12]). Therefore, the improvement in the international terms of trade for corn exports (averaging $633 mil. per year) was more than offset by rectangular deadweight costs in each year (averaging $1,067 mil. per year). Additionally, the net social costs varied significantly, as it depends on the level of oil prices and the level of P_{NE} (which depends on supply and demand shifts in the non-ethanol corn market).

If there were no loan rate program, then the social costs of the tax credit program average $600 mil. (column [13]), slightly lower than before of $683 mil. This is because there is no change in the market price of corn, exports or domestic demand for corn. The tax credit and gasoline prices determine the price of corn. A reduction in ethanol consumption compensates for the reduced production of corn due to the removal of the loan rate. Triangular deadweight costs in production decline, as do tax costs of the tax credit and while the change in rectangular deadweight costs is ambiguous in theory, it declines slightly in this empirical example.

The final column of Table 3 shows that the net social costs of the loan rate program without the tax credit is $713 mil., more than if both polices were in place ($651 mil). This means the tax credit generates a slight increase in net social welfare. This is because of the international terms of trade improvement of $1,205 per year (column [9] minus column [10]). The United States could easily obtain this social gain by restricting exports instead and not having the tax credit, saving both $1,067 mil. in annual rectangular deadweight costs and $3,934 mil. in annual costs to domestic consumers of (column [7] minus [8]). There are other costs of the ethanol tax credit not accounted for like the general equilibrium effects of a spike in food prices increasing the inefficiency of taxes on labor (Goulder and Williams 2003). The empirical simulation presented here is only meant to illustrate the properties of the theoretical model for a single sector and its interaction effect with a price contingent farm subsidy.

If only the tax credit was in place, then tax costs would have averaged $1,523 mil. (column [6] in Table 3), implying the loan rate increased the annual tax costs of the tax credit by an average of $290 mil.[15] Meanwhile, the tax credit reduced the average annual tax costs of deficiency payments, resulting in a net savings of $2,483 mil. in tax costs. But the tax credit incurs rectangular deadweight costs of the tax credit average about $1,082 mil. and increased costs to domestic consumers of $3,934 mil.

Another caveat of the analysis is the assumption that the loan rate set by politicians would not be affected by the tax credit. However, much higher oil and corn prices (and prices for related crops) give politicians an incentive to increase loan rates compared to a situation of no tax credit and lower crop prices with burgeoning taxpayer costs. As shown in Swinnen and de

Gorter (1998), estimates of the welfare effects of one policy assuming the level of the other policy is unaffected can be seriously biased. For example, the recent House Farm Bill proposes an increase in loan rates and target prices for several crops. If the tax credit did not exist, ethanol and hence corn prices would be lower and tax costs of price contingent subsidies higher. As a result, Congress may otherwise have been proposing lower price supports. Hence, the counterfactual may be very different so caution should be exercised in attributing the social benefits of the tax credit in reducing tax costs of price supports.

The effects of a tax credit that varies with oil prices

Because ethanol production is expanding so rapidly and is expected to reach 12 billion gallons by 2010 (Elobeid et al. 2006), the implied tax costs will be $6 bil. Hence, to limit taxpayer exposure, the idea of a variable tax credit has been proposed in Congress (e.g., Senator Lugar 2007) and by academics (e.g., Tyner and Quear 2006). Following Tyner and Quear (2006), we analyze the implications of a scheme where the tax credit is zero once the price of oil reaches $60/barrel and increases 2.5 cents per gallon for each $ per barrel price decline. With an exogenous 20 percent decrease in oil prices for the year 2006/07, water is the same under the two scenarios (a fixed versus variable tax credit) but ethanol production is higher with the variable tax credit. The increase in rectangular deadweight costs are offset by the relative terms of trade improvement in corn exports with the variable tax credit. Market prices for corn decline in each scenario by different amounts but the tax costs of the farm subsidy programs remain zero as loan rates and target prices are not triggered in either case.[16] Although consumers lose more with the variable tax credit, farmers benefit an extra $1.3 bil. while the net social welfare cost is $103 mil.

6. Concluding Remarks

Many countries are implementing a variety of policies to increase biofuel use with consumption tax credits being a prominent method amongst them. Hence, it is very important to understand the effects of such a policy on the markets for agricultural products, biofuels and oil and on economic welfare. To this end, this paper develops a unique general theory to analyze the efficiency and income distribution effects of a tax credit for biofuels. It is a particularly important issue for other countries in the world where gasoline taxes are often far higher than the U.S. case analyzed here. Therefore, rectangular deadweight costs can be even higher in these countries. A stylized model of the U.S. corn market indicates that annual average rectangular deadweight costs for 2001-2006 was $1,056 mil., in addition to the traditional triangular deadweight costs typically calculated in economic welfare studies.

This paper shows that the tax credit reduces costs of the loan rate program but net tax savings may be negative because of foregone tax revenues due to the tax credit itself. Tax savings in farm subsidies are replaced by increases in costs to corn consumers and by part of the tax costs of the tax credit (both due to and independent of the loan rate). The other part of the tax cost of the tax credit represent rectangular deadweight costs, part of which is generated by the loan rate.

The effect of the loan rate on rectangular deadweight costs are to both increase and decrease it (net effect is ambiguous), to eliminate it, to create it, or to have no impact at all. Rectangular deadweight costs increase because of the loan rate (as ethanol production expands with a given level of water) but at the same time decreases the rectangular deadweight costs as it lowers the water in the tax credit for a given level of ethanol production. We prove that the effect of price supports on rectangular deadweight costs depends on whether there is *ex ante* or *ex post* water in the tax credit. Two out of the four outcomes are situations where ethanol production occurs only because of price supports.

Furthermore, we show how the welfare effects of a tax credit depends critically on whether the country is a large country importer or exporter in either the agricultural good used in biofuel production or oil. For large countries (or for the combined effect of all small countries), terms of trade effects in either the oil or the agricultural markets can be positive or negative, depending on the trade status in each market. Algebraic expressions for the effects of these and other market parameters on the impact of the tax credit on efficiency and transfers are formally derived.

The model presented in this paper allows one to analyze the implications of several other policy issues. For example, it is important to understand the impacts of a tax credit on international trade because of the recent controversy over how the U.S. ethanol "subsidy" of 51 cents per gallon should be treated by the WTO. The model developed in this paper shows the tax credit increases the price of both ethanol and corn, thereby conferring no specific subsidy to nor harming either producers of ethanol or corn in the rest of the world.[17] Only the oil industry can be potentially harmed by the subsidy attributed to a consumption tax credit for biofuels.

The model is also well suited to form a basis for evaluating both the social benefits of the tax credit in reducing local pollution, greenhouse gas linked warming and oil dependency and the social costs in adding to traffic congestion, accidents and other negative externalities arising from more fuel consumption (Parry et al. 2007). Hence, this paper provides a springboard to assess the efficacy of alternative policies like a gasoline tax in achieving multiple policy goals like reducing oil dependency and tax costs of farm programs, or improving farm incomes and environmental quality.

In future research, the model can be adapted to analyze other interesting issues, like the effects of subsidies for either ethanol production or R&D of new technologies, and of policies that shift the non-ethanol corn demand curve to the right (import quotas on sugar increases the demand for corn syrup) or that shift the corn supply curve left (subsidies for other crops). In addition to including more agricultural sectors, future research should also relax some assumptions by allowing for decreasing returns to scale in ethanol production, and for endogenous biofuel imports and variation in the additive value of ethanol.

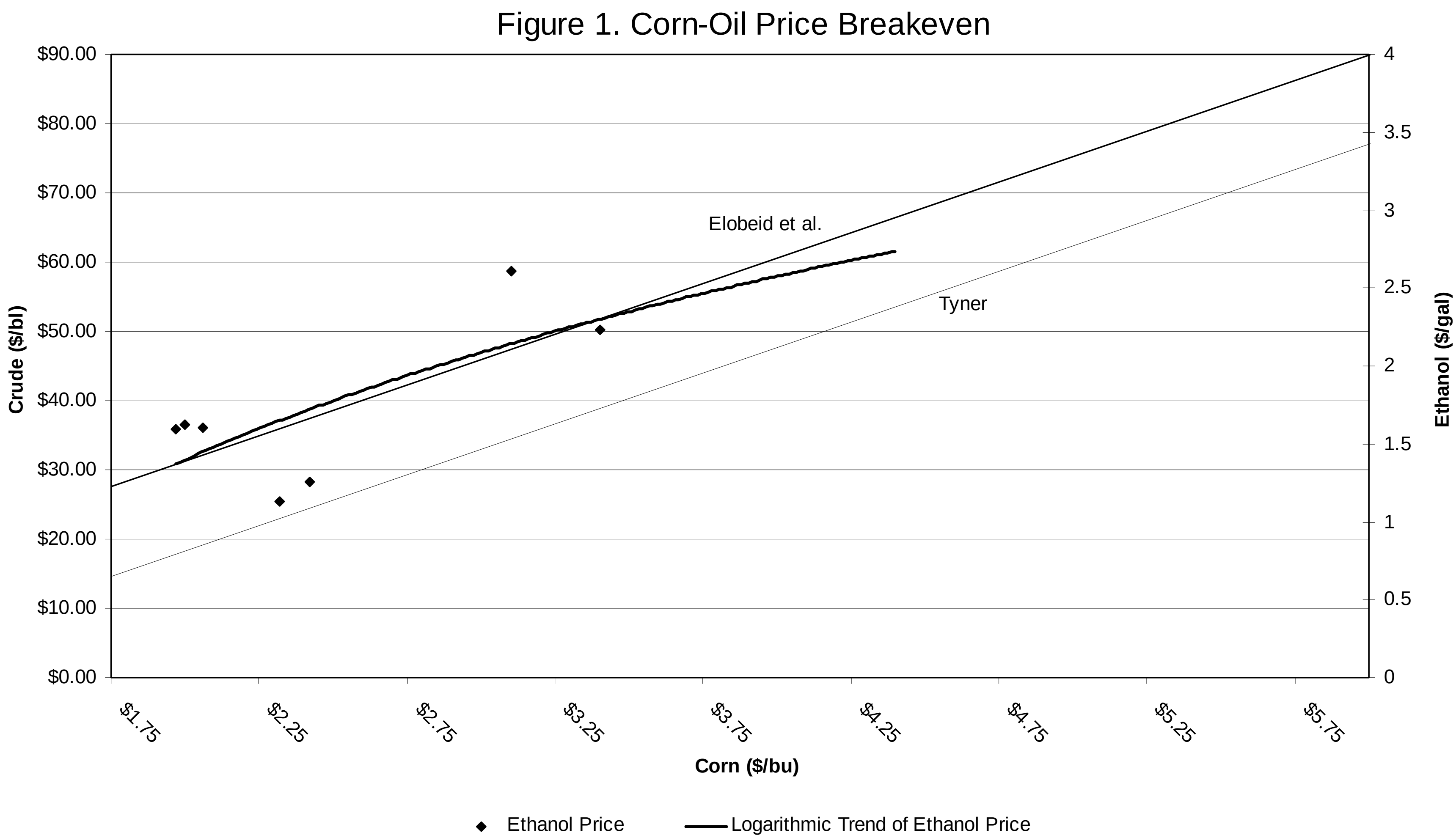
Figure 1. Corn-Oil Price Breakeven
Crude ($/bl)
$90.00
$80.00
$70.00
$60.00
$50.00
$40.00
$30.00
$20.00
$10.00
$0.00
Ethanol ($/gal)
4
3.5
3
2.5
2
1.5
1
0.5
0
Elobeid et al.
Tyner
$1.75
$2.25
$2.75
$3.25
$3.75
$4.25
$4.75
$5.25
$5.75
Corn ($/bu)
Ethanol Price
Logarithmic Trend of Ethanol Price

Figure 2: Market Equilibrium with a Tax Credit

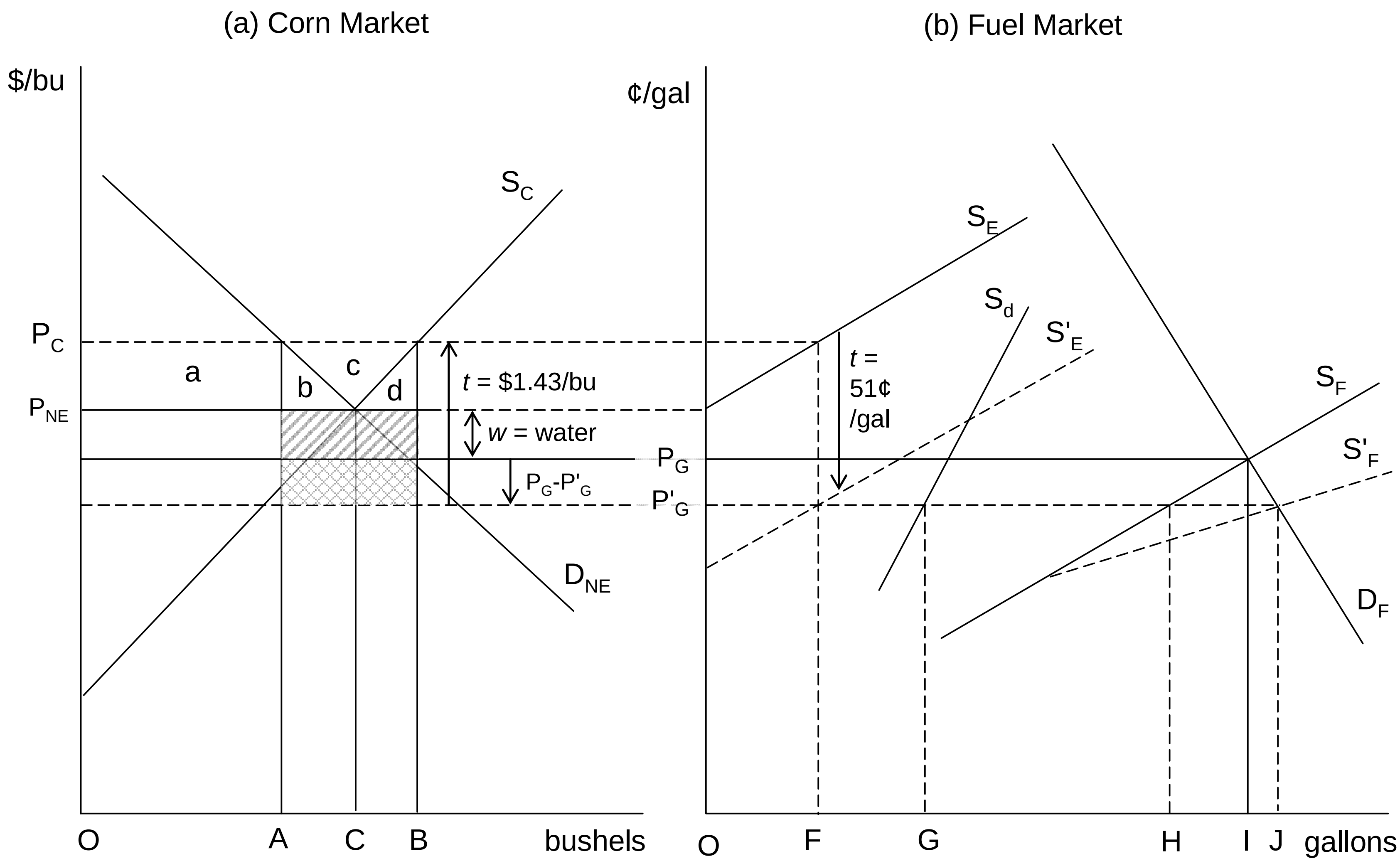

Figure 3: Welfare Economics of a Tax Credit

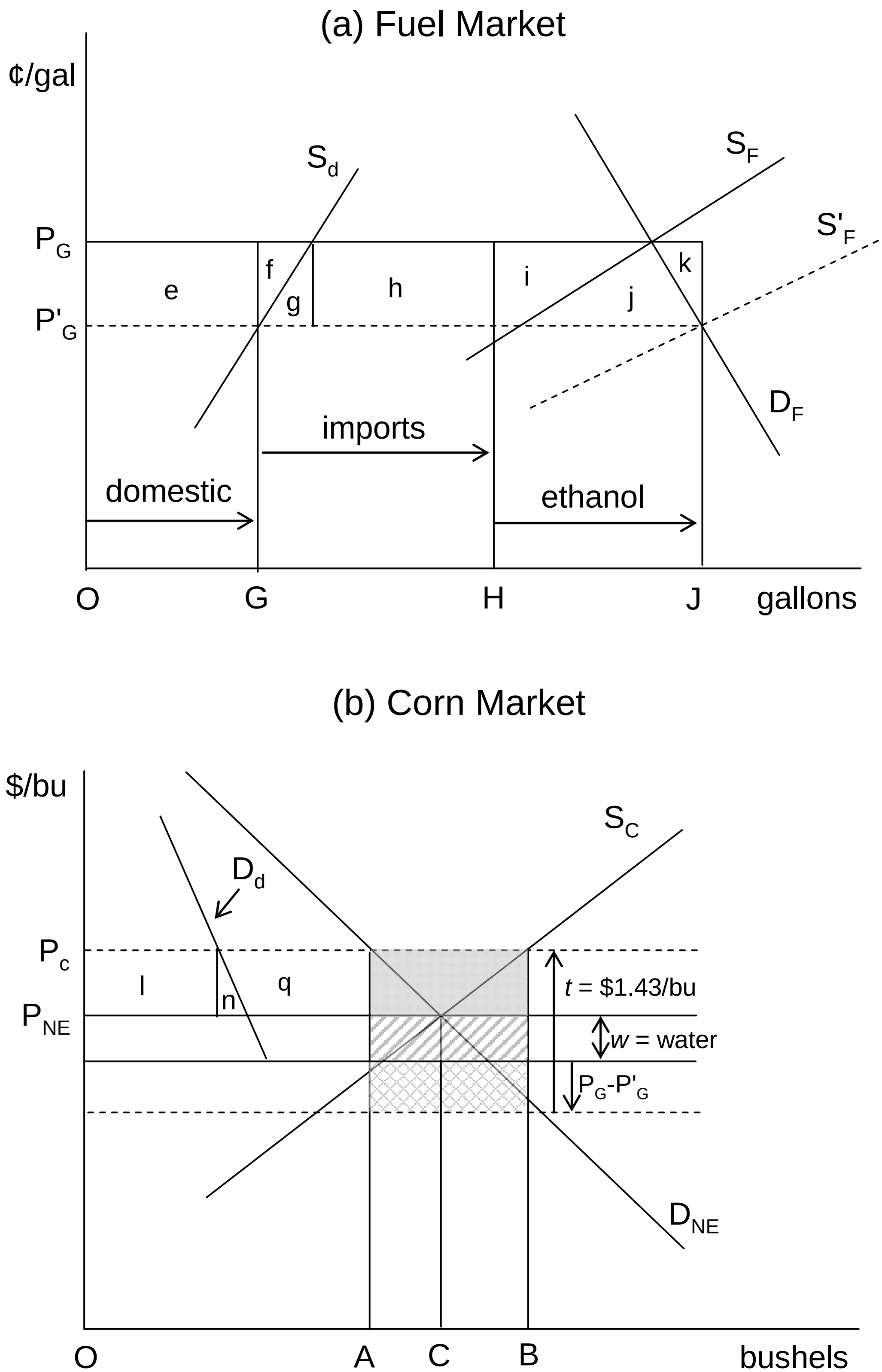

Figure 4a: Ethanol Tax Credit and Deficiency Payments: Corn Price above P_{NE} and Water > 0

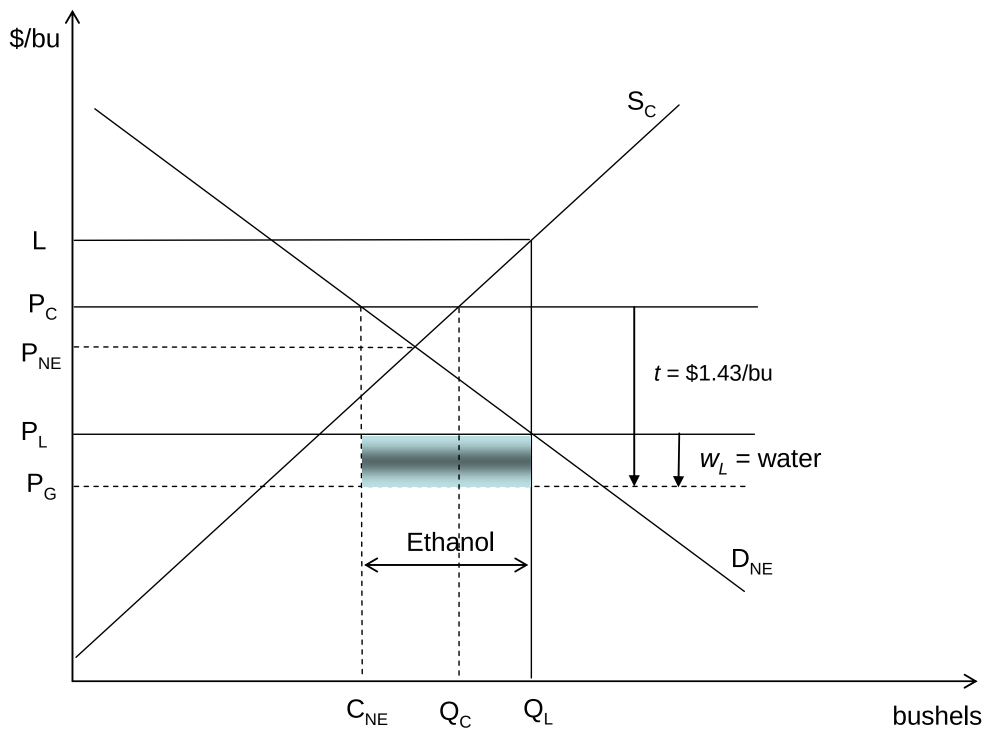

Figure 4b: Ethanol Tax Credit and Deficiency Payments: Corn Price above P_{NE} and Water = 0

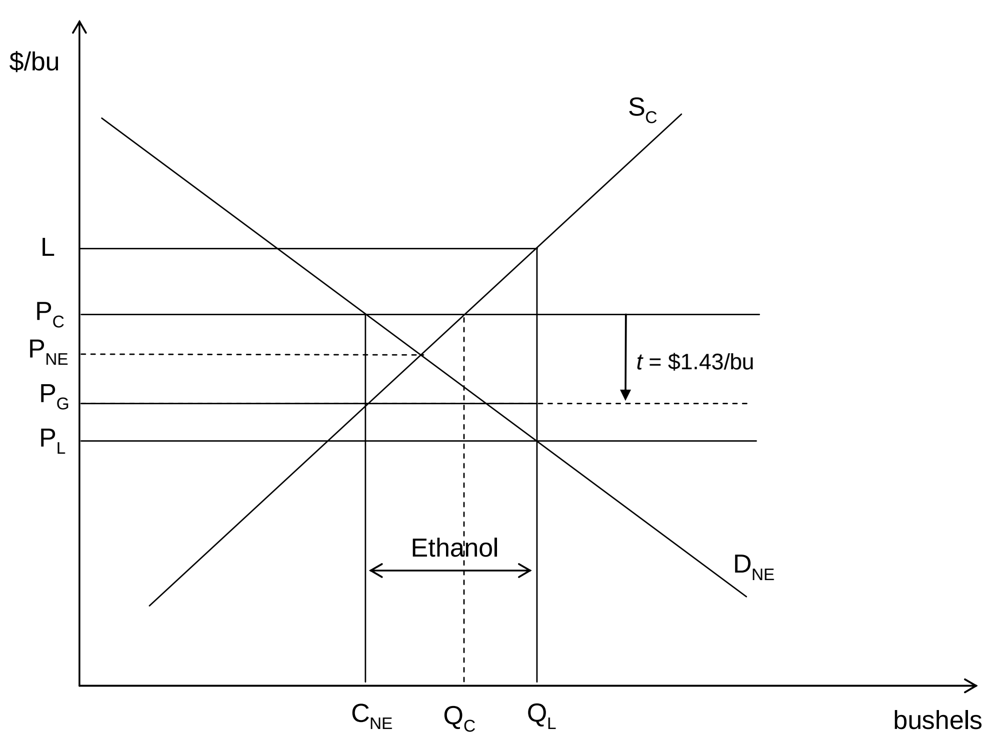

Figure 5a: Ethanol Tax Credit and Deficiency Payments:
Corn Price below P_{NE} and Water > 0

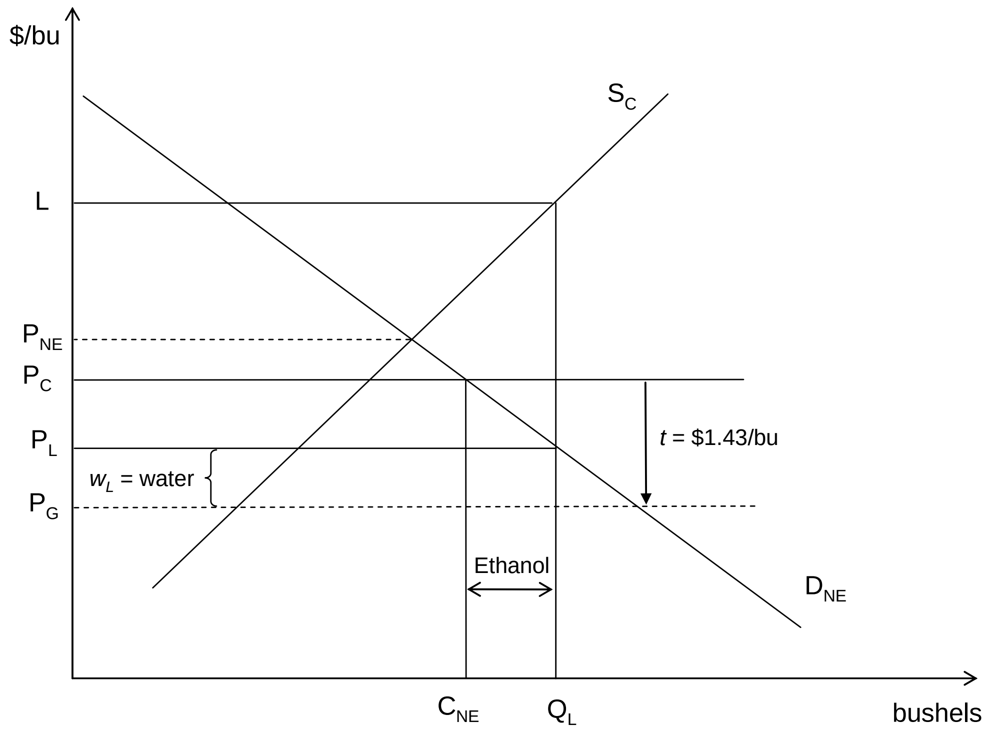

Figure 5b: Ethanol Tax Credit and Deficiency Payments:
Corn Price below P_{NE} and Water = 0

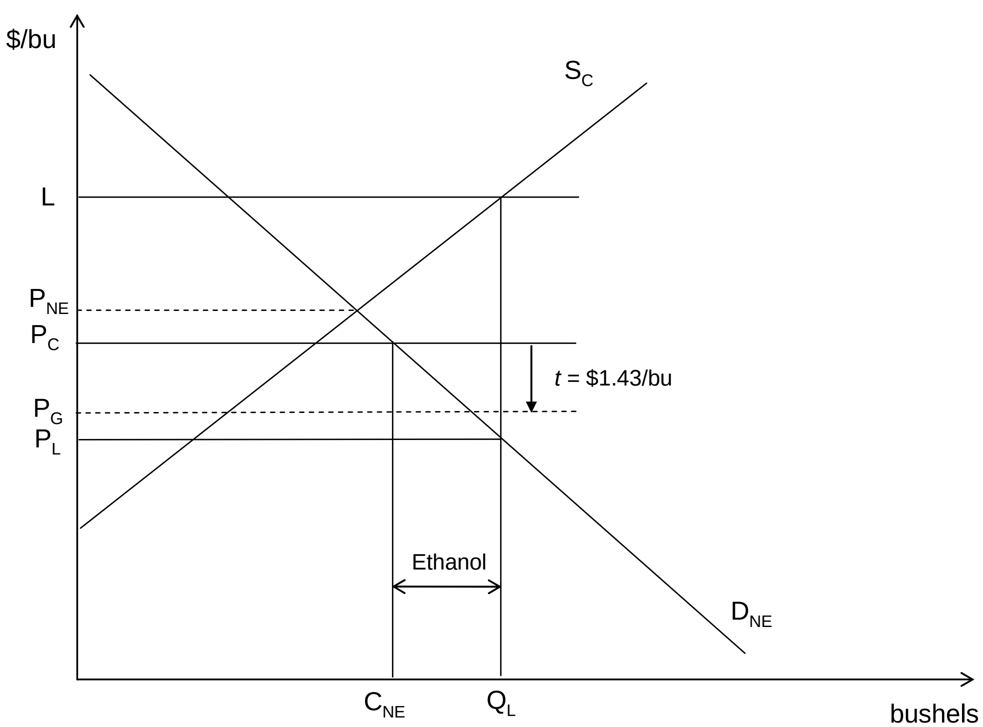

Table 1: Price Contingencies for the Social Welfare Effects of the Tax Credit

	CASE A [Figures 2,3]	CASE B[a]	CASE C1 [Figures 4,5]	CASE C2
Effective Producer Price	$P_c + t > P_{NE}, L$	$P_{NE} > P_c + t, L$	$L > P_c + t, P_{NE}$	
	Gasoline market drives producer corn price	Gasoline price has no effect on corn producers	Loan rate determines supply price for corn	
Effective Consumer Price	$P_c + t > q^{-1D}\left(\pi_1\left(P_c + t\right)\right)$	$P_c + t < q^{-1D}\left(\pi_1\left(P_{NE}\right)\right)$	$P_c + t > q^{-1D}\left(\pi_1\left(L\right)\right)$	$P_c + t < q^{-1D}\left(\pi_1\left(L\right)\right)$
	Gasoline price transmits to corn consumers	Gasoline price has no effect on corn consumers	Gasoline price transmits to corn consumers	Gasoline price has no effect on corn consumers

[a] Because there is no ethanol production, there is no link between corn and gasoline prices.

Table 2: Corn Market Outcomes											
	Consumption			Production at						Taxpayer costs	
						Prices		'water' in tax credit			
	Domestic Non-ethanol	Exports	Ethanol	Market price	Loan rate	Corn	If no ethanol	No loan rate	With loan rate	Tax credit	Deficiency payments
	D_d	X	E	Q_C	Q_L	P_C	P_{NE}	w	w_L		
	- - - mil. bushels - - -					--- $ per bushel ---				--mil. $--	
2001/02	6,930	1,904	668	9,270	9,502	1.97	1.85	1.31	1.09	955	1,195
2002/03	6,575	1,587	804	8,966	8,415	2.32	2.05	1.16	-	1,150	0
2003/04	7,133	1,899	1,057	10,067	10,089	2.42	2.10	1.11	0.82	1,512	134
2004/05	8,666	1,818	1,323	11,521	11,807	2.06	1.81	1.23	0.84	1,892	2,868
2005/06	7,362	2,147	1,603	10,436	11,112	2.00	1.78	1.23	0.79	2,292	4,300
2006/07	6,395	2,200	2,150	10,745	8,926	3.10	2.36	0.69	-	3,075	0
average	7,177	1,926	1,268	10,167	9,975	2.31	1.99	1.12	0.89	1,813	1,416

Source: USDA; calculated

Table 3: Transfers and Deadweight Costs of Ethanol Tax Credit and Loan Deficiency Payments ($ mil.)

	Deadweight Costs				Transfers to producers							Change in net social welfare		
	Triangular		Rectangular		Taxpayers		Consumers				Net gain	Total	If no LDPs	If no tax credit
	production	consumption	Total	If tax credit only	Total	If tax credit only	Domestic		Foreign				(effect of tax credit)	(effect of LDPs)
							Total	No tax credit	Total	No tax credit				
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]
2001/02	55	5	$727	$571	2,150	623	821	-1604	226	-513	2,415	-562	-364	-589
2002/03	57	22	$933	$933	1,150	1150	1,770	0	427	0	2,356	-585	-585	0
2003/04	92	31	$871	$1,153	1,646	1480	2,253	-2190	600	-734	3,534	-395	-670	-860
2004/05	157	27	$1,117	$1,229	4,760	1484	2,125	-3159	446	-866	4,723	-855	-879	-1083
2005/06	317	19	$1,265	$1,119	6,592	1325	1,640	-3323	478	-1320	6,607	-1,123	-712	-1744
2006/07	397	124	$1,489	$1,489	3,075	3075	4,716	0	1,622	0	7,527	-388	-388	0
average	179	38	1,067	1,082	3,229	1,523	2,221	-1,713	633	-572	4,527	-651	-600	-713

Source: calculated

References

EC - European Commission (2007). Member States Reports in the Frame of Directive 2003/30EC http://ec.europa.eu/energy/res/legislation/biofuels_members_states_en.htm.

Eidman, Vernon R. (2007). "Economics and Market Analysis of Energy Crops in Agriculture", Department of Applied Economics, University of Minnesota, April 26.

Elobeid, A., S. Tokgoz, D. J. Hayes. B. A. Babcock and C. E. Hart. (2006). "The Long-Run Impact of Corn-Based Ethanol on the Grain, Oilseed, and Livestock Sectors: A Preliminary Assessment", CARD Briefing Paper [06-BP 49], Iowa State University, November.

Gardner, Bruce (2003). "Fuel Ethanol Subsidies and Farm Price Support: Boon or Boondoggle?" Department of Agricultural and Resource Economics, Working Paper WP 03-11, University of Maryland, October.

GMF (The German Marshall Fund). (2007). "Brazil Grills U.S. on Ethanol Subsidies" FarmPolicy.com, August 23.
http://www.dtnethanolcenter.com/index.cfm?show=10&mid=56&pid=13&mid=65

Goulder, Lawrence H. and Roberton C. Williams III. (2003). "The Substantial Bias from Ignoring General Equilibrium Effects in Estimating Excess Burden, and a Practical Solution", *Journal of Political Economy*, 2003, vol. 111, no. 4:898-927.

IPC (International Food & Agricultural Trade Policy Council). (2006). WTO Disciplines and Biofuels: Opportunities and Constraints in the Creation of a Global Marketplace, IPC Discussion Paper, Washington DC, October.

Jank, Marcos J., Geraldine Kutas, Luiz Fernando do Amaral and Andre M. Nassar. (2007). EU and U.S. Policies on Biofuels: Potential Impact on Developing Countries, The German Marshall Fund, Washington DC.

Kojima, Masami, Donald Mitchell and William Ward. (2007). Considering Trade Policies for Liquid Biofuels. World Bank, Washington DC, June.

Kojima, Masami and Todd Johnson. (2005). Potential for Biofuels for Transport in Developing Countries Energy Sector Management Assistance Programme (ESMAP) World Bank, Washington DC, October.

Lugar, Richard G. (2007). S.162 National Fuels Initiative The Library of Congress, Washington DC., January. http://thomas.loc.gov/cgi-bin/query/z?c110:s.162:

Martinez-Gonzalez, Ariadna, Ian Sheldon and Stanley Thompson (2007). "Estimating the Effects of U.S. Distortions in the Ethanol Market Using a Partial Equilibrium Trade Model", Paper presented at the annual meetings of the American Agricultural Economics Association, Portland, OR, July 29-August 1.

Miranowski, John A. (2007). “Biofuel Incentives and the Energy Title of the 2007 Farm Bill”, Working paper in The 2007 Farm Bill & Beyond, American Enterprise Institute, Washington D.C. http://www.aei.org/research/farmbill/publications/pageID.1476,projectID.28/default.asp

Parry, Ian W. H., Margaret Walls and Winston Harrington. (2007). “Automobile Externalities and Policies”. *Journal of Economic Literature*, June Vol. 45, Issue 2:373-399.

Rajagopal, Deepak and David Zilberman. (2007). “Review of Environmental, Economic and Policy Aspects of Biofuels”, Policy Research Working Paper WPS4341, The World Bank Development Research Group, September.

Redondo, Patricia Carmona. (2007). “An Overview of National Legal and Policy Frameworks for Bioenergy Production, Promotion and Use” Conference paper presented at the Workshop on Economics, Policies and Science of Bioenergy, Ravello, Italy 26-27 July.

Rothkopf, Garten. (2007). A Blueprint for Green Energy in the Americas: Strategic Analysis of Opportunities for Brazil and the Hemisphere. Report prepared for the Inter-American Development Bank, Washington DC.

Runge, C. Ford and Benjamin Senauer (2007) “How Biofuels Could Starve the Poor”, *Foreign Affairs*, Foreign Affairs Council, New York, May/June, Vol. 86, Issue 3, pp. 41-53.

Schnitkey, Gary, Darrel Good and Paul Ellinger. (2007). “Crude Oil Price Variability and its Impact on Break-even Corn Prices”, Farm Economics Facts & Opinion, FEFO 07-11, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, May 30.

Steenblik, Ronald and Juan Simón. (2007). “Biofuels: At What Cost? Government Support for Ethanol and Biodiesel in Switzerland”, The Global Subsidies Initiative of the International Institute for Sustainable Development, Geneva, Switzerland, June.

Swinnen, Jo and Harry de Gorter. (1998). “Endogenous Commodity Policy and the Social Benefits from Public Research Expenditures.” *American Journal of Agricultural Economics*, Vol. 80: 107-115.

Tokgoz, S., A. Elobeid, J. F. Fabiosa, D. J. Hayes, B. A. Babcock, T. Yu, F. Dong, C. E. Hart and J. C. Beghin. (2007). “Emerging Biofuels: Outlook of Effects on U.S. Grain, Oilseed, and Livestock Markets”, Iowa State University Working Paper [07-SR 101], May.

Tyner, Wallace E. (2007). “U.S. Ethanol Policy— Possibilities for the Future” Purdue University Working Paper ID-342-W, West Lafayette, Indiana.

Tyner, Wallace E., and Justin Quear. (2006). “Comparison of a Fixed and Variable Corn Ethanol Subsidy”. *Choices* 21, no. 3(2006): 199-202.

UNCTAD (United Nations Conference on Trade and Development). (2006). The Emerging Biofuels Market: Regulatory, Trade and Development Implications, United Nations, New York and Geneva.

Zilberman, David. (2007). "Interaction of Energy and Agriculture: Policies, Markets and Players", paper presented to the conference sponsored by the Farm Foundation and USDA's Economic Research Service Global Biofuel Developments: Modeling the Effects on Agriculture, Washington DC, February 27.

Appendix

The resulting first order conditions can be written

(A1)
$$q^D\left(1-\frac{\partial\tilde{P}}{\partial t}\right)-q^S\left(1-\frac{\partial\hat{P}}{\partial t}+\frac{\partial s}{\partial t}\right)+q^X-t\left(\frac{\partial q^S}{\partial P}\frac{\partial\hat{P}}{\partial t}-\frac{\partial q^D}{\partial P}\frac{\partial\tilde{P}}{\partial t}-\frac{\partial q^X}{\partial P}\frac{\partial\tilde{P}}{\partial t}\right)-\delta\frac{\partial q^S}{\partial P}\frac{\partial\hat{P}}{\partial t}$$
$$+\lambda\left(\frac{\partial q^S}{\partial P}\frac{\partial\hat{P}}{\partial t}-\frac{\partial q^D}{\partial P}\frac{\partial\tilde{P}}{\partial t}-\frac{\partial q^X}{\partial P}\frac{\partial\tilde{P}}{\partial t}\right)=0,$$

(A2)
$$-q^D\frac{\partial\tilde{P}}{\partial P_c}-q_F^D-t\left(\frac{\partial q^S}{\partial P}\frac{\partial\hat{P}}{\partial P_c}-\frac{\partial q^D}{\partial P}\frac{\partial\tilde{P}}{\partial P_c}-\frac{\partial q^X}{\partial P}\frac{\partial\tilde{P}}{\partial P_c}\right)+\left(\frac{\partial\hat{P}}{\partial P_c}-\frac{\partial\delta}{\partial P_c}\right)q^S-\delta\frac{\partial q^S}{\partial P}\frac{\partial\hat{P}}{\partial P_c}+q_G^S$$
$$+\lambda\left[\frac{\partial q_G^S}{\partial P}+\frac{\partial q_G^X}{\partial P}+k\left(\frac{\partial q^S}{\partial P}\frac{\partial\hat{P}}{\partial P_c}-\frac{\partial q^D}{\partial P}\frac{\partial\tilde{P}}{\partial P_c}-\frac{\partial q^X}{\partial P}\frac{\partial\tilde{P}}{\partial P_c}\right)-\frac{\partial q_F^D}{\partial P}\right]=0,$$

If either $\frac{\partial\hat{P}}{\partial t}$ or $\frac{\partial\tilde{P}}{\partial t}$ are non-zero then we can solve (A1) for λ

$$\lambda=\frac{-q^D\left(1-\frac{\partial\tilde{P}}{\partial t}\right)+q^S\left(1-\frac{\partial\hat{P}}{\partial t}+\frac{\partial\delta}{\partial t}\right)-q^X+\delta\frac{\partial q^S}{\partial P}\frac{\partial\hat{P}}{\partial t}}{\left(\frac{\partial q^S}{\partial P}\frac{\partial\hat{P}}{\partial t}-\frac{\partial q^D}{\partial P}\frac{\partial\tilde{P}}{\partial t}-\frac{\partial q^X}{\partial P}\frac{\partial\tilde{P}}{\partial t}\right)}+t.$$

The definitions $\hat{P}=\max\{P_c+t,P_{NE},L\}$ and $\tilde{P}=\max\{P_c+t,q^{-1D}(\hat{P})\}$, and $\delta=\max\{L-\tilde{P},\ 0\}$ imply the following contingencies:

(i) If $P_c+t>P_{NE},L$ then $\hat{P}=P_c+t$, $\tilde{P}=P_c+t$, $\delta=0$, and substituting into (A2) obtains

$$t=\frac{\left(q^D+q_F^D-q^S-q_G^S+q^X\right)\left(\eta^S\frac{q^S}{q^X}-\eta^D\frac{q^D}{q^X}-\eta^X\right)}{\left(\eta_G^S\frac{q_G^S}{P_c}+\eta_G^X\frac{q_G^X}{P_c}-\eta_F^D\frac{q_F^D}{P_c}\right)\left(\eta^S\frac{q^S}{q^X}-\eta^D\frac{q^D}{q^X}-\eta^X-1\right)}+\frac{P_c}{\left(\eta^S\frac{q^S}{q^X}-\eta^D\frac{q^D}{q^X}-\eta^X-1\right)}$$

(ii) If $L>P_c+t>P_{NE}$ or $L>P_{NE}>P_c+t>P_L$ then $\hat{P}=L$, $\tilde{P}=P_c+t$, $\delta=L-P_c-t$, and substituting into (A2) obtains

$$t = \frac{\left(-q^D - q_F^D + q^S + q_G^S - q^X\right)\left(-\eta^D \frac{q^D}{q^X} - \eta^X\right)}{-\left(\eta_G^S \frac{q_G^S}{P_c} + \eta_G^X \frac{q_G^X}{P_c} - \eta_F^D \frac{q_F^D}{P_c}\right)\left(-\eta^D \frac{q^D}{q^X} - \eta^X + 1\right)} + \frac{P_c}{\left(-\eta^D \frac{q^D}{q^X} - \eta^X + 1\right)}$$

(iii) If $L > P_{NE} > P_L > P_c + t$ then $\hat{P} = L$, $\tilde{P} = P_L$, $\delta = L - P_L$. The tax credit does not appear in (A1), hence an optimum obtains when $t = 0$.

(iv) If $P_{NE} > P_c + t, L$ then $\hat{P} = P_{NE}$, $\tilde{P} = P_{NE}$, $\delta = 0$. The tax credit does not appear in (A1), hence an optimum obtains when $t = 0$. ■

Endnotes

[1] Exempted or reduced biofuel excise taxes cover 65 percent of total world fuel consumption and are known to be in effect in Argentina, Australia, Brazil, Canada, China, Colombia, EU, Ghana, Honduras, India, Indonesia, Paraguay, Philippines, South Africa, Switzerland, Thailand, Uruguay and the United States (Redondo 2007; Kojima et al. 2007; UNCTAD 2006; Steenblik and Simón 2007; Rothkopf 2007). To help achieve EU wide biofuel consumption targets, 19 Member States have implemented excise tax exemptions and another 5 are planning to do so (EC 2007).

[2] The U.S. biofuel tax exemption was changed to a tax credit in 2004 but this was a change in implementation only and does not affect the economics of the program. The term "tax credit" is used hereafter in this paper.

[3] The import tariff on ethanol is another potential gain in the U.S. terms of trade but we assume ethanol imports are exogenous in the model. The tariff was implemented to offset the benefit exporters would otherwise obtain from the higher price of ethanol induced by the tax credit.

[4] Although we refer to the U.S. ethanol market as we develop our theory in this paper, it is only an example as the model can be applied to any biofuel market with a tax credit. For small countries, the oil price is fixed and there may be no terms of trade effect in the agricultural product market. Indeed, the effect of U.S. ethanol policy on the world price of oil is empirically small for historical levels of ethanol production, even though the United States is a large country importer of oil.

[5] Eidman (2007), Miranowski (2007) and Schnitkey et al. also provide estimates of a linear corn-oil price breakeven relationship.

[6] Ethanol is a substitute for gasoline derived from petroleum. The term "fuel" in this paper refers to the ethanol/gasoline mixture. Ethanol can be up to 10 percent of the fuel mixture in traditional combustion engines with virtually no modifications required.

[7] The tax credit is not adjusted to a BTU basis because gasoline stations do not always label the ethanol content nor do most consumers convert the advertised price into a BTU basis. However, this is not the case in other countries, notably Brazil, and will likely change in the future for the United States as well when ethanol becomes a much larger share of fuel use. The model will then have to be adjusted accordingly.

[8] In cases where water in the tax credit does not exist, in addition to the tax costs of increased ethanol production induced by the tax credit that displaces gasoline consumption, taxpayers would also forego revenues on ethanol that would have been produced without the tax credit.

[9] World prices of oil decline and as an importer, the United States benefits as a result. Normally, an optimal import tariff is a subsidy on domestic oil production and an equal tax on domestic oil consumption. Here, the opposite occurs with domestic oil production taxed and domestic oil consumption subsidized. The outcome is unique because of the way in which the tax credit affects the ethanol and hence oil markets.

[10] Normally an export tax improves a country's international terms of trade which is a tax on domestic production and an equal subsidy on domestic consumption. In the case evaluated here, the opposite occurs: corn producers are subsidized and domestic non-ethanol corn consumers are taxed because the ethanol tax credit increases the world market price for corn.

[11] Because U.S. ethanol production in 2006 is estimated to be 0.211 percent of world petroleum consumption, a fixed oil price in the empirical analysis is a plausible assumption.

[12] The mathematical expression for the effect of the tax credit t on net tax costs of the loan rate L in Figures 5a,b is the same as for that in Figures 4a,b but the effect of the loan rate on the net tax costs of the tax credit differs slightly and is now given by $w_L \cdot (Q_L - C_{NE})$.

[13] In other words, P_C exceeded P_{NE} by \$0.31/bu on average.

[14] The estimates for deadweight loss triangles are in line with those obtained by Gardner (2003) and Martinez-Gonzalez et al. (2007) but these studies omit rectangular deadweight costs.

[15] Annual average costs of the tax credit were $1,813 mil while that of the loan rate was $1,416 mil. (Table 2).

[16] Because corn prices decline more with a fixed tax credit, under other circumstances, there would be additional savings in tax costs of farm programs with a variable tax credit.

[17] Nevertheless, the United States notifies the Agreement on Subsidies and Countervailing Measures in the WTO of the revenues foregone with the biofuel tax credit as a subsidy but categorizes it as an industrial product (IPC 2006). In regards to the recent case filed with the WTO on U.S. farm subsidies, Brazil argues the biofuel subsidy should be included in the domestic support disciplines of the WTO's Agreement on Agriculture but the U.S. response was "the case is about agriculture, not ethanol" (GMF 2007). Either way, our model shows that the tax credit would not constitute a specific subsidy nor have adverse effects on ethanol, corn or sugar producers in the rest of the world. Brazil should instead focus on the U.S.'s 54 cents per gallon import tariff on ethanol that prevents Brazil from taking advantage of this increase in ethanol price. The elimination of the so-called "subsidy" due to the tax credit while maintaining the import tariff would make things even worse for Brazil.

OTHER A.E.M. WORKING PAPERS

WP No	Title	Fee (if applicable)	Author(s)
2007-12	The Impact of the Market Information Service on Pricing Efficiency and Maize Price Transmission in Uganda		Mugoya, M., Christy, R. and E. Mabaya
2007-11	Quantifying Sources of Dairy Farm Business Risk and Implications		Chang, H., Schmit, T., Boisvert, R. and L. Tauer
2007-10	Biofuel Demand, Their Implications for Feed Prices		Schmit, T., Verteramo, L. and W. Tomek
2007-09	Development Disagreements and Water Privatization: Bridging the Divide		Kanbur, R.
2007-08	Community and Class Antagonism		Dasgupta, I. and R. Kanbur
2007-07	Microfinance Institution Capital Structure and Financial Sustainability		Bogan, V., Johnson W. and N. Mhlanga
2007-06	Farm Inefficiency Resulting from the Missing Management Input		Byma, J. and L. Tauer
2007-05	Oil, Growth and Political Development in Angola		Kyle, S.
2007-04	The Impact of Generic Fluid Milk and Cheese Advertising on Regulated Dairy Product Markets: A System Dynamics Analysis		Nicholson, C. and H. Kaiser
2007-03	Should Egalitarians Expropriate Philanthropists?		Dasgupta, I. and R. Kanbur
2007-02	Poverty, Relative to the Ability to Eradicate It: An Index of Poverty Reduction Failure		Kanbur, R. and D. Mukherjee
2007-01	Poverty, Inequality and Conflict		Kanbur, R.
2006-24	Intermediate Product Trade and Domestic Policy Options in the US Dairy Sector		Nicholson, C. and P. Bishop
2006-23	Historical and Spatial Analysis of High-Value Crops Production in the U.S.		Cheng, M., Bills, N. and J. Francis
2006-22	Exploring Voting Anomalies Using a Demand Revealing Random Price Voting Mechanism		Messer, K., Poe., G., Rondeau, D., Schulze, W. and C. Vossler

Paper copies are being replaced by electronic Portable Document Files (PDFs). To request PDFs of AEM publications, write to (be sure to include your e-mail address): Publications, Department of Applied Economics and Management, Warren Hall, Cornell University, Ithaca, NY 14853-7801. If a fee is indicated, please include a check or money order made payable to Cornell University for the amount of your purchase. Visit our Web site *(http://aem.cornell.edu/research/wp.htm)* for a more complete list of recent bulletins.