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Welfare Changes from the U.S. Ethanol Tax Credit: The Role of Uncertainty and Interlinked Commodity Markets

Mindy Baker

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**Center for Agricultural and Rural Development
Iowa State University
Ames, Iowa 50011-1070
www.card.iastate.edu**

Mindy Baker is a research assistant in the Department of Economics and Center for Agricultural and Rural Development at Iowa State University.

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Questions or comments about the contents of this paper should be directed to Mindy Baker, 75 Heady Hall, Iowa State University, Ames, IA 50011-1070; Ph: (515) 294-5452; Fax (515) 294-6336; E-mail: bakermin@iastate.edu.

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Abstract

A model of the corn, soybean, and wheat markets calculates welfare effects of the U.S. ethanol tax credit. Crop yields are uncertain, and demand consists of feed, food, energy, and exports. Modeling uncertainty in crop yields allows the valuation of deficiency payments as options. Disaggregating demand records who benefits from the tax credit and by how much; incorporating linked crop markets captures indirect effects important for determining the transfer from consumers to producers. There is \$600 million in net welfare loss, increased taxpayer liability, and a large transfer from consumers to farmers. A brief comparison of recent literature is included.

Keywords: biofuel, commodity, ethanol, tax credit, uncertainty, welfare.

Welfare Changes from the U.S. Ethanol Tax Credit: The Role of Uncertainty and Interlinked Commodity Markets

Who gains from tax credits granted to the ethanol industry, and by how much? The increase in grain prices associated with ethanol production shifted government spending from price deficiency programs to ethanol subsidies. Deficiency payments are only made in years when market prices are low, whereas ethanol payments occur every year. The size of payments in the price deficiency programs depend explicitly on uncertainty in crop prices. Therefore, in order to compare the old program to the new we need to introduce price uncertainty into our models of welfare analysis. We include uncertainty in crop yields, which drives uncertainty in equilibrium crop prices and allows us to estimate change in the option value of government deficiency payments.

We also include two markets closely linked to corn—soybeans and wheat. This is an important element for which to account because farmers do not plant one crop; they typically plant a rotation of crops. Therefore, it is important to quantify the welfare changes in those closely related markets as well.

For each commodity, we disaggregate demand, allowing us to disentangle welfare effects felt by major segments of commodity consumers, including the livestock feeding sector, the food sector, and exports. Knowing which sectors are most impacted by biofuel policy changes is important information for policymakers to consider.

We conclude the article by comparing our results with those found recently in the literature. The comparison demonstrates the importance of including these three features

of the bioeconomy—uncertainty in crop yields, indirect effects on linked commodity markets, and disaggregated consumer demand—in our welfare models.

The Model Economy

The economy has three goods: corn, soybeans, and wheat. Consumers buy agricultural commodities and use them as input in producing food, feed, or energy, or for export, and we introduce uncertainty through agricultural commodity yields. In the first period, agents form expectations about prices and future crop yields, and farmers allocate acreage among corn, soybeans, and wheat. In the second period, crop supply is determined by acreage allocations and crop yield realizations. Demand from the biofuel sectors is determined by biofuel capacity, and demand for the commodities also comes from food and export consumers.

Commodity Supply

There exists a single representative and competitive farmer with an endowment of one unit of land, who takes both output prices and his cost function as given. While output prices and yields are uncertain, all agents in the economy know the joint distribution.

The farmer allocates his land in period one to three different crops: corn, soybeans, and wheat. The endowed land is representative of total U.S. cropland devoted to these commodities. Since cellulosic ethanol from crop land does not pass the Energy Independence and Security Act (EISA) net carbon standard, ethanol from biomass with a low opportunity cost of land (like corn stover) is most likely to be the first source of commercial cellulosic ethanol (Searchinger et al. 2008). For this reason, we exclude a cellulosic biomass crop that competes for land with corn, soybeans, and wheat in our

model.

We index the crops as follows: corn, $i = 1$; soybeans, $i = 2$; and wheat, $i = 3$. The producer's second-period profit is given by

$$(1) \quad w = \sum_{i=1}^3 p_i \zeta_i \pi_i - c_i(\pi_i; \Theta_i)$$

where \tilde{p}_i is crop i 's output price, and the quantity produced of crop i is $Q_i(\cdot)$. The nominal cost function for crop i is $c_i(\pi_i; \Theta_i)$, where Θ_i is a vector of parameters defining each crop's nominal cost function — nominal meaning it does not account for the opportunity cost of the land. The proportion of land allocated to crop i is π_i , and production technology is characterized by $\frac{\partial c_i}{\partial \pi_i} > 0$.

The producer is risk neutral in profit, wishing to maximize the present value of expected profit subject to land constraints. To this end, he chooses an allocation vector π to solve the problem:

$$(2) \quad \max_{\pi} E[w] \quad s.t. \quad \sum_{i=1}^n \pi_i = 1 \quad \text{and} \quad \pi_i \geq 0 \quad \text{for } i=1, 2, 3$$

The first-order conditions are

$$(3) \quad p_2^t \frac{\partial Q_2^t}{\partial \pi_2} + \frac{\partial c_2^t}{\partial \pi_2} = p_1^t \frac{\partial Q_1^t}{\partial \pi_1} + \frac{\partial c_1^t}{\partial \pi_1}$$

$$(4) \quad p_3^t \frac{\partial Q_3^t}{\partial \pi_3} + \frac{\partial c_3^t}{\partial \pi_3} = p_1^t \frac{\partial Q_1^t}{\partial \pi_1} + \frac{\partial c_1^t}{\partial \pi_1}$$

These conditions require that the producer equate the marginal net benefit of growing soybeans (wheat) to the marginal net benefit of growing corn, and that the

solution to the farmer's acreage allocation problem is defined as $\pi^*(\mathbf{p}; \Theta, \zeta)$.

Multiplying the acreage decisions with the production functions, we get the commodity supply for each crop given the random yield realizations, ζ . Notice both price and nominal cost of producing other crops enter a given crop's supply function,

$$Q_i(\mathbf{p}; \Theta, \zeta) = \zeta_i \pi_i^*(\mathbf{p}; \Theta, \zeta).$$

Functional Forms for Commodity Supply

We assume the nominal cost functions of the crops are quadratic, given by

$$c_i(\pi_i) = a_i \pi_i + \kappa_i (\pi_i)^2 \quad \forall i = 1, 2, 3.$$

The proportion of land allocated to each crop, π_i , is the farmer's choice variable; the parameters of the cost function (a_i and κ_i) depend on the price of crude oil. This specification works well because we can separate out increasing and constant marginal production costs, and use the commodity cost and return budgets of the Economic Research Service (ERS) as estimates for these.¹

We parameterize the production function for the agricultural commodities as

$$(5) \quad Q_i(\mathbf{p}; \Theta, \zeta) = \zeta_i \pi_i^*(\mathbf{p}; \Theta, \zeta) \quad \text{for } i = 1, 2, 3$$

The yield realizations, ζ , are drawn from the joint beta distribution of yields using the algorithm developed by Magnussen (2004).

$$\zeta \sim \beta \left(\begin{bmatrix} \mu_{corn} \\ \mu_{soybean} \\ \mu_{wheat} \end{bmatrix}, \Sigma^{-1}, \mathbf{q}_{max}, \mathbf{q}_{min} \right)$$

$$\Sigma^{-1} = \begin{bmatrix} 228.08 & 39.71 & 1.58 \\ 39.71 & 10.83 & 0.312 \\ 1.58 & 0.312 & 0.031 \end{bmatrix}, \quad \mathbf{q}_{\max}^f = \begin{bmatrix} \mu_{\text{corn}} + 3\sigma_{\text{corn}} \\ \mu_{\text{soybean}} + 3\sigma_{\text{soybean}} \\ \mu_{\text{wheat}} + 3\sigma_{\text{wheat}} \end{bmatrix}$$

$$\mathbf{q}_{\min}^f = \begin{bmatrix} \mu_{\text{corn}} - 2\sigma_{\text{corn}} \\ \mu_{\text{soybean}} - 2\sigma_{\text{soybean}} \\ \mu_{\text{wheat}} - 2\sigma_{\text{wheat}} \end{bmatrix}$$

Trend yields are important (especially for corn), so we set the mean at the 2007 trend level.² The matrix Σ^{-1} is the variance-covariance matrix for the yields of the three crops, and the σ are the standard deviations of each crop found in Σ^{-1} .³

Commodity Demand

With an aggregated demand function, we are only able to consider changes in *aggregate* welfare, while disaggregating commodity demands allows us to explore welfare changes to different groups resulting from biofuel expansion.

We model demand for each commodity from four different subsectors: livestock feed (*l*), direct human food use (*f*), exports (*x*), and energy (*e*). For the demand equations, own- and cross-price elasticities are those used in the ERS/Penn State/World Trade Organization trade model for livestock feed, food/consumer demand, and export demand. We use own- and cross-price elasticities of beef and veal feed demand in the United States. We use food/consumer demand elasticities for the corn, soybean, and wheat food demand parameters in our model. We calibrate the constant terms to 2007 consumption levels for each group. Tables 1 and 2 contain parameter estimates of the supply and demand equations used in the Monte Carlo simulation.

Corn Demand Equations

$$\begin{aligned}
Q_i^{d_c,t} &= \alpha_0^c (p_c^t)^{\alpha_1^c} (p_{sb}^t)^{\alpha_2^c} \\
Q_f^{d_c,t} &= \beta_0^c (p_c^t)^{\beta_1^c} \\
Q_x^{d_c,t} &= \gamma_0^c (p_c^t)^{\gamma_1^c} \\
Q_e^{d_c,t} &= \delta_c n_c^t \\
Q^{d_c,t} &= Q_e^{d_c,t} + Q_x^{d_c,t} + Q_f^{d_c,t} + Q_l^{d_c,t}
\end{aligned}
\tag{6}$$

Where p_i^t is the price of crop i at time t . The corn-based ethanol industry size at time t is represented by n_c^t .⁴ We include the price of soybeans in the corn feed demand equation but assume only own-price effects in the food and export sectors.

The Soybean Complex

Demand for soybeans is composed of crush demand and exports. Crush demand is obviously driven by demand for soybean meal and oil, and we assume this affects aggregate demand for soybeans in proportion to the amount of oil verses meal found in the soybean seed. Figure 1 shows the relationship of aggregate soybean demand to all of its components. Aggregate soybean demand comes from the domestic crush market and exports; crush demand comes from demand for soybean meal and soy oil. Demand for soybean meal is driven exclusively by the livestock-feeding sector, and we include a corn cross-price elasticity. Demand for soy oil, however, comes from both food demand and biodiesel production.

Crush demand depends upon the price of soy oil and soybean meal, not the price of soybeans directly. However, the prices of these link tightly to the price of soybeans,

and for simplicity we estimate a simple deterministic linear relationship of each with the price of soybeans using recent data.⁵

Wheat Demand Equations

For the wheat demand equations we include only demand from the food and exports. Only a small amount is used for livestock feeding and biofuel production.

$$\begin{aligned}
 Q_f^{d_w,t} &= \beta_0^w (p_c^t)^{\beta_1^w} \\
 Q_x^{d_w,t} &= \gamma_0^w (p_w^t)^{\gamma_1^w} \\
 Q^{d_w,t} &= Q_x^{d_w,t} + Q_f^{d_w,t} + Q_l^{d_w,t}
 \end{aligned}
 \tag{7}$$

Competitive Equilibrium

In our economy, a competitive equilibrium is defined by

$$\begin{aligned}
 &\text{pricing functions } p_i(\zeta, \varepsilon, \mathbf{n}) \text{ for } i = 1, 2, 3 \\
 &\text{crop demand functions } Q_i^d(\mathbf{p}, n_i) \text{ for } i = 1, 2, 3 \\
 &\text{crop supply functions } Q_i^s(\mathbf{p}; \Theta, \zeta) \text{ for } i = 1, 2, 3
 \end{aligned}
 \tag{8}$$

Given the pricing functions, biofuel capacity, and crop yield realizations, commodity markets clear. That is, $Q_i^s(\mathbf{p}^*; \Theta, \zeta) = Q_i^d(\mathbf{p}^*, n_i^*)$ for $i = 1, 2, 3$.

Calculating Welfare Changes

This modeling framework allows us to calculate the welfare of five different groups: farmers, livestock producers, processors of cereal grains and oilseeds for food use, gasoline consumers or blenders, and taxpayers. Suppose \mathbf{p} is the equilibrium price vector in the status quo scenario, and $\hat{\mathbf{p}}$ is the equilibrium price vector after some policy

change. Calculating the change in welfare of the farmer is a straightforward calculation of producer surplus:

$$(9) \quad \Delta PS_{farmer} = \int_Y \frac{\partial \Pi_{farmer}}{\partial p_c} dp_c + \frac{\partial \Pi_{farmer}}{\partial p_{sb}} dp_{sb} + \frac{\partial \Pi_{farmer}}{\partial p_w} dp_w$$

where Y is an arbitrary curve in the price space with endpoints \mathbf{p} and $\hat{\mathbf{p}}$, ΔPS_{farmer} is the change in producer surplus of the farmer, and Π_{farmer} is the profit function of the farmer.

Path independence of a line integral of a continuous, conservative function over an open, connected region, along with Hotelling's lemma, imply ΔPS_{farmer} is equivalent to (Larson, Hosteltler, and Edwards 2002; Mas-Colell, Whinston, and Green 1995):

$$(10) \quad \begin{aligned} \Delta PS_{farmer} = & \int_{p_c}^{\hat{p}_c} Q_c^s(\mathbf{p}; \Theta, \tilde{\zeta}, s^{-1}) dp_c \\ & + \int_{p_{sb}}^{\hat{p}_{sb}} Q_{sb}^s(\mathbf{p}; \Theta, \tilde{\zeta}, s^{-1}) dp_{sb} + \int_{p_w}^{\hat{p}_w} Q_w^s(\mathbf{p}; \Theta, \tilde{\zeta}, s^{-1}) dp_w \end{aligned}$$

Agricultural commodities like corn, soybeans, and wheat are not retail goods; very little if any of these are sold directly to end consumers. These commodities are used as inputs in the production processes of food, meat, and fuel. Since these are input demands for production processes, this allows us to calculate the welfare change here as the standard consumer surplus measure. Profit-maximizing firms do not exhibit a difference in willingness to pay versus willingness to accept since their input demands are derived from their cost function and not from a quasi-concave utility function like an individual consumer.

Notice that by including cross-effects of corn prices on soybean meal demand and soybean meal prices on corn demand, the direction of change in welfare due to a policy

change is a priori unknown. Because of the substitutability of the corn and soybeans, for example, if the equilibrium price of corn increases, we have a shift along the demand curve for corn, but we have a shift out in the crush demand equation due to the increase in the corn price. And likewise is the effect of an increase in the price of soybean meal on the corn market. See figure 2 for an illustration of these direct and indirect welfare changes. For this reason, when a policy causes all commodity prices to rise, in equilibrium there is a welfare loss due to the increase in the commodity's own price. At the same time there is a welfare gain due to the demand curve shifting out because the price of the substitute has increased as well.

By Shepherd's lemma and Larson, Hosteltler, and Edwards, again the change in the producer's surplus is given by

$$\begin{aligned}
 \Delta PS_l &= \int_Y \frac{\partial C_l}{\partial p_c} dp_c + \frac{\partial C_l}{\partial p_{sb}} dp_{sb} \\
 (11) \quad &= \int_{p_c}^{\hat{p}_c} (Q_l^{d_c} + Q_{l-sbmeal}^{d_{sb}}) dp_c + \int_{p_{sb}}^{\hat{p}_{sb}} (Q_l^{d_c} + Q_{l-sbmeal}^{d_{sb}}) dp_{sb}
 \end{aligned}$$

where $C_l(\cdot)$ is the cost function for livestock producers.

Corn, soybeans, and wheat all are used in the production of food for human consumption. Corn is used to make sweeteners and corn meal, soybeans make their way into human diets directly through soybean oil and soy-based dairy or protein replacements, and wheat is consumed as flour or pasta. In this way, we distinguish the welfare change of the wheat food-producing sector from the corn food-producing sector from the soybean food-producing sector in a similar manner as for the livestock producers:

$$\begin{aligned}
\Delta PS_{f-corn} &= \int_Y \frac{\partial C_{f-corn}}{\partial p_c} dp_c \\
&= \int_{p_c}^{\hat{p}_c} Q_f^{d_c} dp_c \\
\Delta PS_{f-sb} &= \int_Y \frac{\partial C_{f-sb}}{\partial p_{sb}} dp_{sb} \\
&= \int_{p_{sb}}^{\hat{p}_{sb}} Q_f^{d_{sb}} dp_{sb} \\
\Delta PS_{f-wheat} &= \int_Y + \frac{\partial C_{f-wheat}}{\partial p_w} dp_w \\
&= \int_{p_w}^{\hat{p}_w} Q_f^{d_w} dp_w
\end{aligned}
\tag{12}$$

and similarly for exports of each of the commodities:

$$\begin{aligned}
\Delta PS_{ex-corn} &= \int_Y \frac{\partial C_{ex-corn}}{\partial p_c} dp_c \\
&= \int_{p_c}^{\hat{p}_c} Q_{ex}^{d_c} dp_c \\
\Delta PS_{ex-sb} &= \int_Y \frac{\partial C_{ex-sb}}{\partial p_{sb}} dp_{sb} \\
&= \int_{p_{sb}}^{\hat{p}_{sb}} Q_{ex}^{d_{sb}} dp_{sb} \\
\Delta PS_{ex-wheat} &= \int_Y + \frac{\partial C_{ex-wheat}}{\partial p_w} dp_w \\
&= \int_{p_w}^{\hat{p}_w} Q_{ex}^{d_w} dp_w
\end{aligned}
\tag{13}$$

Taxpayer Costs

Taxpayers have two potential sources of expenditures: the blender's credit and deficiency payments to farmers. Loan deficiency payments (LDPs) are like cash settled put options written by the taxpayers and owned by farmers. When the market price of the commodity is below the target rate, the taxpayer makes a payment of the difference to the farmers based on the amount of the commodity they own. Countercyclical payments (CCPs) are

made when the effective price of a commodity is less than the target price for the commodity, and the payment is based on historical yields and recent acreage allocations. See figure 3 for a depiction of the payoffs of the LDP and CCP programs.

Since these deficiency payment programs have option-like characteristics, we can only value them appropriately in a model that accounts for uncertainty in commodity markets. When buying an option on an exchange, the owner pays a premium upfront for the privilege to enjoy market upside potential, without exposure to downside risks. The loan rate⁶ (LR) of the loan deficiency program is the strike price of this option; taxpayers subsidize farmers through LDPs without receiving the option premium from the farmers. Calculating the option value of the loan deficiency program is more accurate than assuming the market price will be above or below the loan rate based on historical prices. Most welfare analysis is conducted based on calculating a deterministic equilibrium corn price based upon fixed demand and supply assumptions. Our model allows for uncertainty in the price of corn, soybeans, and wheat through uncertain yields, and allows us to calculate the cost to taxpayers (in terms of option premium lost) in a more realistic way than if we were using a deterministic model.

The value of the LDP payment is the value of a put option with harvest-time maturity and strike price equal to the loan rate, LR . In reality, the value of this option would vary through the crop-growing season and would not remain constant. Because of decreasing time to maturity, and also because weather shocks are realized through the season and uncertainty about supply is resolved, the option either becomes more in-the-money or out-of-money, which changes its value. However, for the purpose of this study

we consider the value of the option at planting time for that crop—spring and early summer for corn and wheat, respectively, and fall for wheat. We assume only winter wheat in our analysis since the U.S. produces significantly more winter than spring wheat⁷ and dealing with only one type simplifies the analysis. The put option written by the government has a value of

$$(14) \quad \text{put}(p_c^t, LR, T) = \mathbf{exp}(rT) E^* \left[\mathbf{max}(LR - p_c^T, 0) \right]$$

$$(15) \quad \text{put}(p_{sb}^t, LR, T) = \mathbf{exp}(rT) E^* \left[\mathbf{max}(LR - p_{sb}^T, 0) \right]$$

$$(16) \quad \text{put}(p_w^t, LR, T) = \mathbf{exp}(rT) E^* \left[\mathbf{max}(LR - p_w^T, 0) \right]$$

for corn, where r is the risk-free interest rate (assumed constant), T is the time from planting to harvest, and $E^*(\cdot)$ is the expectation operator under the equivalent martingale measure. We choose planting time as the reference point from which we value the put option because if it were not for the government loan deficiency program, farmers could purchase the same protection against low market prices on the appropriate commodity exchange and presumably would do so simultaneously with their planting decisions. Therefore, the loan deficiency program is a transfer in the amount of the option value from taxpayers to farmers.

CCPs are similar to LDPs, but they are determined not by the current season's production but by past production. Payments are made when the target price⁸ is lower than the effective price for the commodity. The effective price is

$$(17) \quad \text{Effective Price} = \text{Direct Payment Rate} + \mathbf{max}(p_{\text{market}}, LR)$$

The direct payment rate portion of the effective price is constant and not determined by production, so this portion of the payment will not contribute to welfare changes in our analysis. CCPs are made according to the following calculation:

(18)

$$CCP = \max[(Target\ Price - Effective\ Price), 0] \times 0.85 \times Base\ Acres \times Historical\ Yield$$

The CCP is thus an option held by the farmer as well; if the market price falls between the target price and the loan rate, the farmer exercises the option and receives a payment based on historical production.

At planting time, the value of the CCP option is

(19)

$$CCP(p^t, Target, Effective, T) = e^{-rT} E^* [\max(Target - Effective, 0)] \times 0.85 \times BA \times HY$$

and the net payment of the deficiency payment programs as a function of harvest time price is that of a put option with strike price equal to the target, but the farmer receives a payment (instead of paying a premium) for holding the option.

Results

In table 3 we present the welfare results from our simulation. We simulate crop prices with the ethanol tax credit of \$4.11 for corn, \$11.69 for soybeans, and \$10.11 for wheat. Without the tax credit we simulate crop prices of \$3.17, \$8.43, and \$6.74 for corn soybeans, and wheat, respectively.⁹ The first result of note is that under the blender's credit, government expenditures (the farm program and ethanol tax credit combined) are not reduced. Taxpayers were net losers—by nearly \$144 million—under the current biofuel program in 2007. The welfare loss to taxpayers is because the reduced option

value of the deficiency payment programs (\$542 mil CCP and \$2,629 mil LDP)¹⁰ is not enough to offset the additional cost of the ethanol tax credit. The reduced deficiency payment option value comes at the expense of farmers. They are the owners of this option, and under the biofuel program they lose \$3.2 billion on this option.

Farmers are not net losers, however. The deficiency payments lose value because the increase in demand for corn causes the equilibrium prices of all commodities to be higher—and drives the deficiency payment options out of the money, reducing their value. High market prices more than compensate the farmer for the reduction in this option value, though. Farmers are better off by \$7.4 billion in the corn market, by \$7.1 billion in the soybean market, and by \$8.7 billion in the wheat market; in total, farmer's net welfare gain from the 2007 ethanol tax credit is \$23.2 billion.

Gasoline consumers or blenders receive welfare gains from the ethanol tax credit in an amount equal to taxpayer liability from the blender's credit, \$3.32 billion. We do not model how much of this welfare gain is retained by the blenders and how much is passed through to retail gasoline consumers. However, Du and Hayes (2008) examine the effect of the ethanol industry on retail gasoline prices and find that ethanol production has reduced retail gasoline prices by \$0.29 to \$0.40 per gallon depending on the region. This suggests that blenders pass at least some of the welfare gains on to retail gasoline consumers.

So far the results are all positive concerning the ethanol subsidy; all groups considered have enjoyed net welfare gains: taxpayers, farmers, and gasoline consumers or blenders. In our analysis, one group collectively finances this transfer. The consumers

of agricultural commodities experience a large welfare loss of \$26.9 billion. The largest losers are foreign users of agricultural commodities. Consumers demanding corn, soybeans, and wheat for export had welfare losses of \$10 billion. Next, the domestic livestock feeding industry loses \$9.3 billion in welfare, and the food processing industry loses \$7.6 billion. These entities are intermediate demanders of agricultural commodities, but, assuming these markets are competitive, these welfare losses are passed on to retail consumers.

This results in an aggregate welfare loss of \$597 million. We also are able to calculate distributions over the net welfare change simulated in our model (see figure 4); in our simulation there is no mass over positive net welfare changes. This indicates that in our model aggregate deadweight losses will occur with near certainty.

Comparison with the Existing Literature

Separating the welfare effects among producers, taxpayers, and the various types of agricultural consumers is a tricky undertaking, and several papers recently address the task. A side-by-side comparison of these studies is provided in table 4. The aggregate welfare change estimates range from -\$5,733 to \$1,281.

De Gorter and Just (2008) calculate the welfare effects of the U.S. ethanol tax credit and note that “water” in the tax credit causes significant rectangular welfare losses. In their modeling framework they include the corn market with demand disaggregated into foreign and domestic producers, with the excess supply of corn absorbed by the ethanol industry. They then model the fuel market to calculate the effect of ethanol in the domestic fuel market. They find net welfare losses from the ethanol tax credit.

Schmitz, Moss, and Schmitz (2007) calculate the welfare costs and benefits of U.S. ethanol production, and find a positive aggregate welfare gain. The driver of this result is that while tax revenue is decreased because of the blender's tax credit, taxpayer liabilities are reduced by more than this amount because subsidies to corn farmers are reduced, but the authors use a deterministic model. They separate out the welfare effects to non-ethanol users of corn between food, alcohol, and industrial use versus feed and residual use.

Du, Hayes, and Baker (2008) perform welfare analysis focusing on the fuel markets for both gasoline and ethanol on an energy-equivalent basis and the market for corn. They find the net welfare effect of ethanol production to be negative. Babcock (2008) uses a deterministic model of the ethanol and corn markets, distinguishing demand for corn as coming from feed, food, and exports. A later piece written simultaneously with this one by McPhail and Babcock (2008) uses a similar model but incorporates uncertainty in corn yields, corn demand, and ethanol demand. This study does not consider cross-market effects with soybeans and wheat.

Gardner (2007) uses a deterministic model of the ethanol market, including corn producers, users of corn including ethanol, feed and exports, taxpayers, ethanol producers, and ethanol consumers.

Our study is the only one of those studies considered here to recognize that a reduction in farm program payments causes a reduction in farmer surplus as well as a decrease in taxpayer cost because the farm program payment is effectively an option farmers own and the taxpayer is obligated to honor. In an aggregate welfare analysis, we

should include this reduction of farmer surplus from the decreased value of the deficiency payment options they hold before we add back in the benefit that farmers received from higher prices. Notice also that if we did not subtract this decreased option value from the farmer's surplus change we would calculate a net welfare gain from the ethanol tax credit of \$2.5 billion. Our study is also the first to include the indirect effect on the interlinked markets of soybeans and wheat.

The range of estimates among these articles illustrates how sensitive welfare studies are to model assumptions—particularly to the structure imposed. A model that assumes a market functioning in isolation will yield quantitatively different results than a model that includes market interaction in a richer set of linked markets; every piece left out distorts the picture of where transfers are going, the size of aggregate transfer, and deadweight loss. For example, notice in our analysis that the size of transfer from consumers to producers is larger than in the other articles. This is because ignoring the soybean and wheat market effects understates the size of the distortion. Even when a gain by one group is a loss in the same amount by another group, it is important to record these transfers because of their implications for policy decisions.

Conclusion

The U.S. ethanol policy results in a transfer from consumers of agricultural commodities to producers (farmers). Consumers of retail fuel also receive welfare gains, but this amount is dwarfed by the size of transfer from consumers to producers caused by the increase in equilibrium market prices. Also, we find a modest increase in taxpayer outlays under the ethanol tax credit. We compare our study with a survey of several

recent welfare analyses. Previous studies left out one or more salient features of these markets; e.g., linkages among commodity markets in both production and consumption and uncertainty in commodity yields.

Including linkages among commodity markets is important because with scarce fertile crop ground, incentives implemented increasing the equilibrium price of one crop increases the equilibrium price of all crops competing for acreage. We include corn, soybeans, and wheat to capture these linked market effects, and our measure of farmer gain and consumer loss is larger than in the welfare studies to which we compare our work. Including multiple crop markets also gives a more realistic estimate of the effect to taxpayers through the reduced deficiency payment liabilities. Also, including uncertainty in crop yields allows us to better quantify the reduction in the deficiency payment liability to the taxpayer.

Endnotes

¹ Available at <http://www.ers.usda.gov/Data/CostsAndReturns/>. Parameters are calibrated to the most recent estimates available (2006 crop year). We use fertilizer cost as a proxy for increasing marginal cost, κ_i , and all other operating costs as constant marginal cost, a_i .

² We assume yields follow a linear trend. We estimate the trend from yield data (per harvested acre) for the years 1980 through 2006. Available at <http://www.nass.usda.gov/>

$$\mu_{corn}^t = -3843.83 + 1.99t, \quad \mu_{soybean}^t = -993.52 + .52t, \quad \mu_{wheat}^t = -460.50 + 0.25t$$

³ We estimate the var-cov matrix of the crop yields from the historical data above as well.

⁴ The amount of biofuel of type i in operation is given by n_i^t in billion gpy. Therefore, δ_0^i represents the amount of feedstock used annually by the industry.

⁵ We estimate the relationship between the price of soy oil and soybeans from daily nearest contract prices on the CBOT from Oct. 17, 2005, to Sept. 14, 2007. For soybean meal we use daily nearest contract prices of soybean meal and soybeans on the CBOT from April 30, 2007, to March 3, 2008. $Soy\ Oil\ Price^t = 0.044 p_{sb}^t - 0.009$,

$$R^2=0.878. \quad Soybean\ Meal\ Price^t = 33.53 + 0.23(p_{sb}^t \cdot 100), \quad R^2 = 0.929.$$

⁶ The loan rates for corn, soybeans, and wheat are \$1.95, \$5.00, and \$2.75, respectively (see <http://www.ers.usda.gov/Briefing/FarmPolicy/malp.htm>).

⁷ In 2007 there were 1.87 billion bushels of winter wheat, and 0.55 billion bushels of spring wheat produced in the U.S. (see www.nass.usda.gov).

⁸ Information about the countercyclical payment program is available at <http://www.ers.usda.gov/Briefing/FarmPolicy/CounterCyclicalPay.htm>. Target prices for corn, soybeans, and wheat are \$2.63, \$5.80, and \$3.92, respectively.

⁹ Ethanol production was 6.5 billion gallons per year in 2007, so in our model we simulate the price changes from an increase to this production level.

¹⁰ Actual average government expenditures for all support and related programs was \$3,437 mil for corn, \$384 mil for soybeans, and \$2,160 for wheat for the years 1990-2000 (see http://www.fsa.usda.gov/Internet/FSA_File/pb08_book3.pdf).

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Table 1. Supply parameters used in Monte Carlo simulation

	Corn	Soybeans	Wheat
κ_i	80.17	11.08	28.44
a_i	125.81	85.78	56.57

Table 2. Demand parameters used in Monte Carlo simulation

	Corn	Soybeans	Wheat
α_0^i	10.8	4.15	--
α_1^i	-0.258	0.081	--
α_2^i	0.002	-0.379	--
β_0^i	1.5	2.8	2
β_1^i	-0.059	-0.150	-0.05
γ_0^i	1.894	1.455	1.2
γ_1^i	-0.01	-0.01	-0.01
δ_i	0.357	0.69	--

Note: Units of demand equations are billion bushels.

Table 3. Results for 2007 crop year (millions of dollars)

		Corn	Soybeans ^a	Wheat	Totals
<i>Ag Producers</i>					
Market	(+)	\$8,219.60	\$8,451.25	\$9,669.79	\$26,340.64
Lost CCP	(-)	(\$392.60)	(\$105.19)	(\$44.00)	(\$541.79)
Lost LDP	(-)	(\$474.23)	(\$1,206.00)	(\$948.98)	(\$2,629.22)
Total		\$7,352.77	\$7,140.06	\$8,676.81	\$23,169.63
<i>Ag Consumers</i>					
Feed	(-)	(\$6,777.74)	(\$2,608.32)		(\$9,386.06)
	(+)	\$43.80	\$43.14		\$86.94
	total	(\$6,733.94)	(\$2,565.18)		(\$9,299.12)
Food	(-)	(\$1,251.92)	(\$596.66)	(\$5,785.93)	(\$7,634.51)
Export	(-)	(\$1,702.65)	(\$4,480.28)	(\$3821.33)	(\$10,004.26)
Total		(\$9,688.51)	(\$7,642.12)	(\$9,607.26)	(\$26,937.89)
<i>Gasoline Cons/ Blenders</i>	(+)				\$3,315.00
<i>Taxpayers</i>					
CCP	(+)	\$392.60	\$105.19	\$44.00	\$541.79
LDP	(+)	\$474.23	\$1,206.00	\$948.98	\$2,629.22
Blender's Credit	(-)				(\$3,315.00)
Total		\$866.83	\$1,311.19	\$992.98	(\$143.99)
Net Change					(\$597.25)

^a Welfare change in the crush market attributed to proportion of soybean meal (feed) and oil (food) coming from the soybean crush process

Table 4. Comparison of recent welfare studies (millions of dollars)

	Babcock 2008	Baker 2008 (current study) ^a	de Gorter & Just 2008	Du, Hayes, & Baker 2008	Gardner 2007	McPhail & Babcock 2008	Schmitz, Moss, & Schmitz 2007
<i>Ag Producers</i>							
Market	\$14,393	\$26,341	\$1,484	\$14,050	\$425	\$1,581	\$1,154
Lost CCP		(\$542)					
Lost LDP	--	(\$2,629)	(\$3,508)	--	--	--	--
Total	\$14,393	\$23,170	(\$2,024)	\$14,050	\$425	\$1581	\$1,154
<i>Ag Consumers</i>							
Feed	(\$6,126)	(\$9,299)		--	--	(\$730)	(\$1,008)
Food	(\$1,251)	(\$7,635)	(\$1,484)	--	--	(\$197)	(\$3,094)
Export	(\$1,955)	(\$10,004)	\$433	--	--	(\$276)	(\$993)
Total	(\$9,332)	(\$26,938)	(\$1,051)	(\$16,170)	(\$322)	(\$1,203)	(\$5,095)
<i>Gasoline Cons/ Blenders</i>	\$2366	\$3,315	\$1,606	\$1,150	\$2406	\$2,337	\$3883
<i>Taxpayers</i>							
LDP	--	\$3,171	\$3,508	\$3,450	--	--	\$4,084
Blender's Credit	(\$13,160)	(\$3,315)	(\$3,330)	(\$3,260)	(\$2,600)	(\$1,391)	(\$2,761)
Total	(\$13,160)	(\$144)	\$178	\$190	(\$2,600)	(\$1,391)	\$1,323
Net Change	(\$5,733)	(\$597)	(\$1,291)	(\$780)	(\$91)	(\$568)	\$1,281

^a Includes soybean and wheat market calculations as well as corn, whereas the other studies only consider corn.

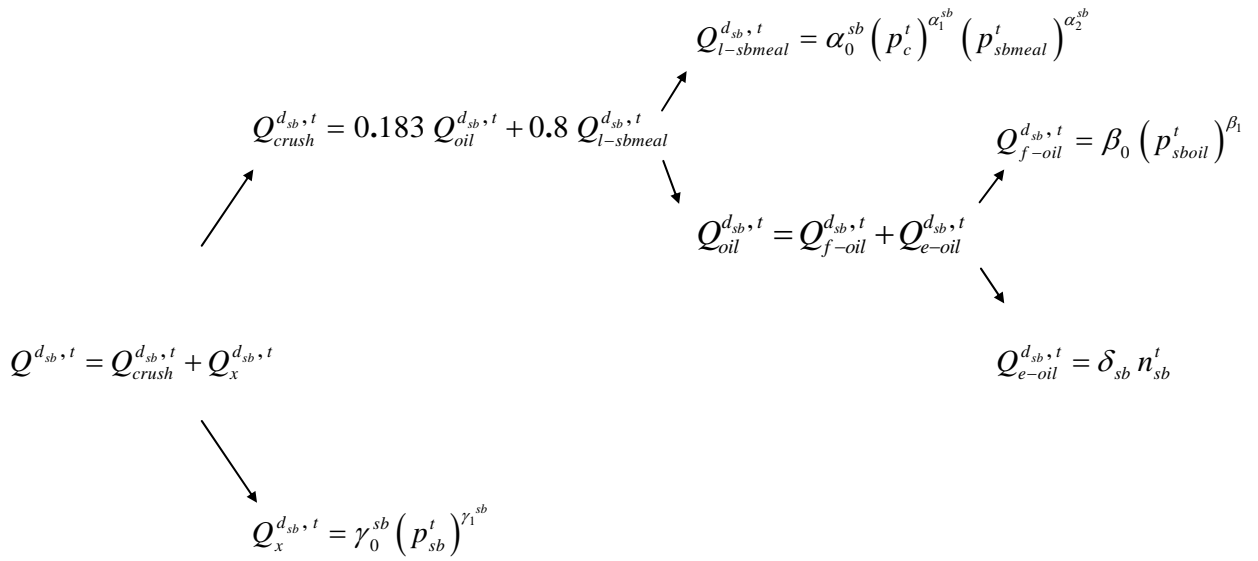


Figure 1. Relationship of aggregate soybean demand to all of its components

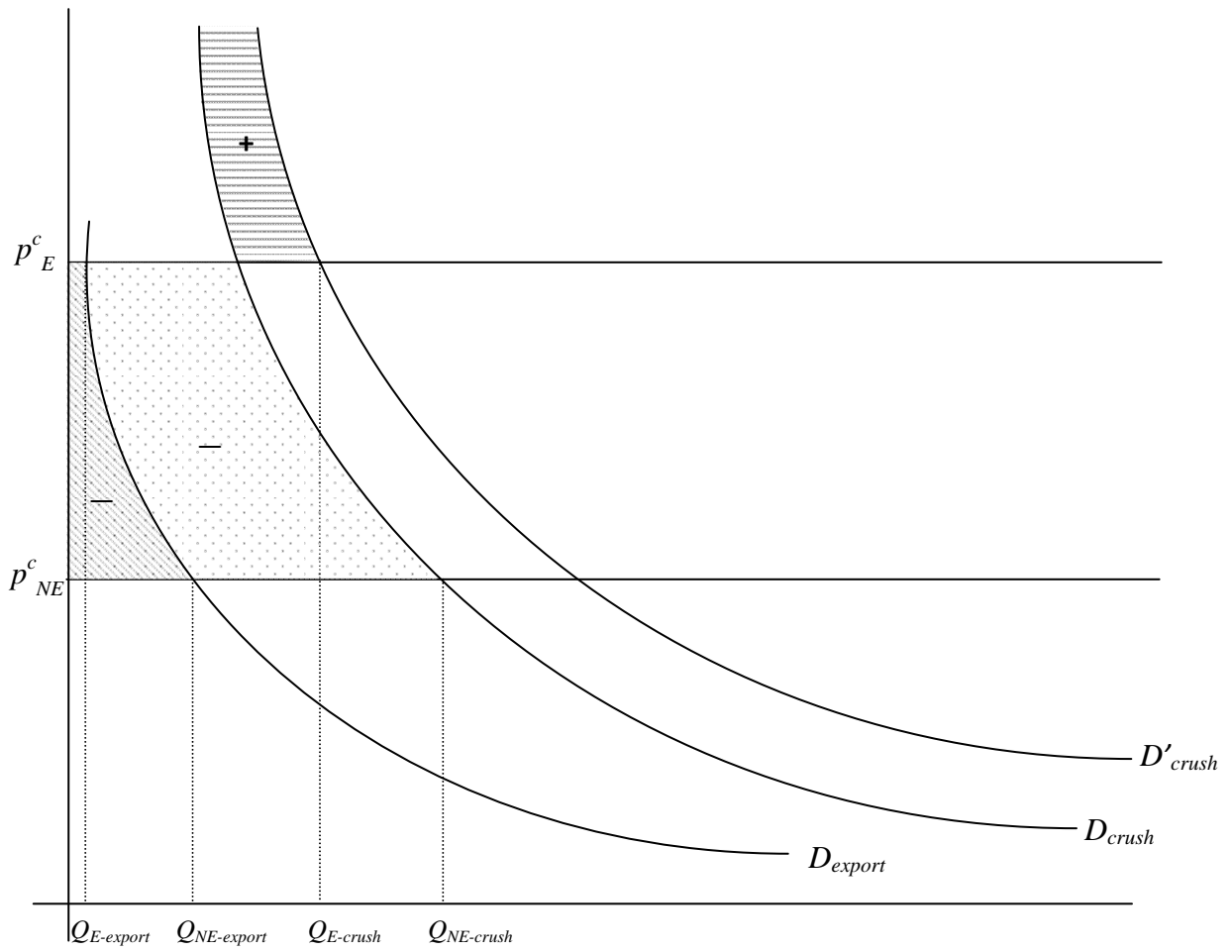
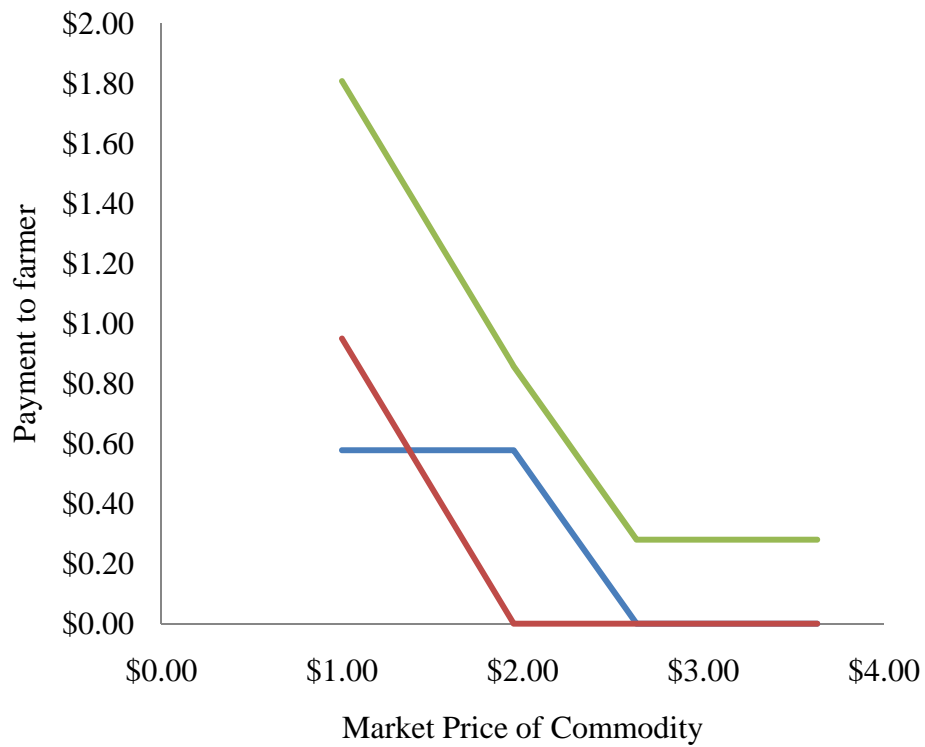


Figure 2. DWL in the soybean market distortion and cross-market effects



- CCP
- LDP
- Total Payment

Note: Corn market is depicted with a \$1.95 loan rate, \$2.63 target price, and \$0.28 direct payment. The CCP is made on 85% of base acres, and LDP is made on actual production. To make this figure we calculate the total payment using on the same quantity of grain for CCP and LDP payments.

Figure 3. Deficiency payments to farmer as a function of market prices

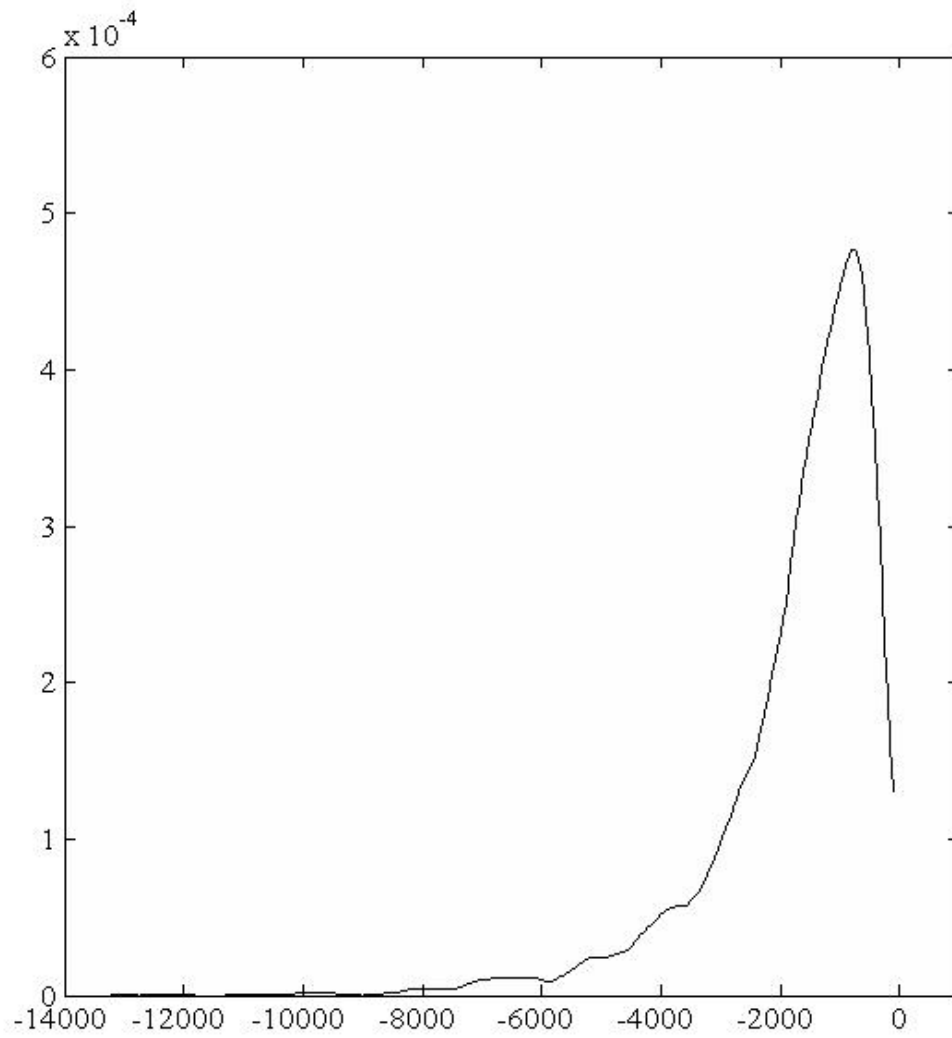


Figure 4. Distribution of net welfare change from the ethanol blender's credit (millions of dollars)