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# **A Welfare Analysis of the U.S. Ethanol Subsidy**

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## **Abstract**

Based on a transparent analytical model of multiple markets including corn, ethanol, gasoline, and transportation fuel, this study estimates the welfare changes for consumers and producers resulting from ethanol production and related support policies in 2007. The welfare estimation takes into account the second-best gain from eliminating loan deficiency payments. The results suggest the total social cost is about \$0.78 billion for given market parameters. We validate the model's underlying assumption and test for the results' sensitivity to assumed parameters.

**Key words:** consumer surplus, deadweight loss, ethanol, subsidy, substitution.

*JEL* classification: D6, Q18, Q21.

## Introduction

The ethanol industry in the United States receives support on several different fronts.

There are three major categories:

1. Budgetary support measures, including a 51¢-per-gallon tax credit to refiners blending ethanol with gasoline. This is scheduled to fall to 45¢ in January 2009.
2. A renewable fuel standard (RFS) that requires U.S. fuel producers to blend into gasoline at least a certain amount of renewable fuel, ranging from 9 billion gallons in 2008 to 36 billion gallons by 2022.
3. Trade restrictions, including a 2.5% ad valorem tariff and a per unit tariff of 54¢ per gallon.

The benefits and pitfalls of this level of government support have been at the center of recent debate.

In this study we investigate the distribution of welfare gains and losses from the ethanol blenders tax credit among producers and consumers in the corn, ethanol, gasoline, and fuel markets and estimate the overall welfare impact of the U.S. ethanol subsidy. To the best of our knowledge, our study is the first to include the impact of ethanol on the gasoline market, and to acknowledge in a multimarket framework that prior to the existence of a large ethanol industry, commodity markets were already in a second-best situation.

There are an increasing number of studies on the topic. Babcock simulates the welfare impacts of various government ethanol policies in a model of multiple integrated markets. He finds that U.S. ethanol policy induces a large welfare transfer from taxpayers and non-ethanol corn users to corn producers, fuel blenders, and ethanol producers, as well as

large associated net welfare loss. Gardner uses a vertical market model of corn, ethanol, and by-products and compares welfare effects of the government subsidy on corn through deficiency payments and the government subsidy on ethanol produced from corn. He finds that the net deadweight loss of the corn and ethanol subsidies is likely to be in the billions of dollars annually. The deadweight loss of the ethanol subsidy is much higher than that of deficiency payments. This conclusion is based on the assumption that the corn price increases by only 4¢ from the ethanol subsidy, an amount that is much lower than we use below. Schmitz, Moss, and Schmitz calculate the impact of ethanol subsidies on corn used for ethanol and indicate that the treasury cost of the ethanol tax credit is about \$1.0 billion lower than the cost of direct payment to corn farmers.

Martinez-Gonzalez, Sheldon, and Thompson use a partial equilibrium trade model and a back-of-envelope formula to calculate welfare effects of distortions in the ethanol market. Elobeid and Tokgoz analyze the impact of trade liberalization and removal of the U.S. federal tax credit on ethanol markets, excluding energy markets, in a multimarket international ethanol framework. They find that trade liberalization induces a welfare loss for ethanol and corn producers and a gain in consumer surplus through lower ethanol and corn prices. Also, the removal of the tariff and tax credit results in declines in the surplus of corn farmers, ethanol producers, and ethanol consumers. De Gorter and Just analyze the efficiency and income distribution effects of the ethanol tax credit and illustrate the potential welfare effects. They find a net deadweight loss of \$1.07 billion per year. Taheripour and Tyner find that the share of the ethanol subsidy received by ethanol producers (1) increases with the elasticity of substitution between ethanol and gasoline and also with the proportion of ethanol blended in fuel, and (2) decreases with the price

elasticity of ethanol. They conclude that the ethanol industry is, and will continue to be, in a good position to capture the ethanol credit regardless of its current share.

Our paper differs from the existing literature in several important ways. First, we develop an analytical model explicit in its accounting of ethanol, gasoline, and fuel markets.<sup>1</sup> Second, we estimate the welfare impacts on agricultural and energy markets, and on overall welfare change after accounting for reduced loan deficiency payments. We estimate welfare changes by both traditional consumer (producer) surplus formulas and the compensating variation measure. Finally, we validate the model's underlying assumptions and test for sensitivity of the main results to market parameters.

### **The Analytical Model**

In the model, the corn market includes ethanol and non-ethanol demand and corn supply. The fuel market includes gasoline and ethanol separately to disentangle the relationship between these markets and better capture the substitution effect of ethanol on gasoline. We provide a graphical illustration of the corresponding welfare changes in terms of consumer and producer surplus. This study does not explicitly evaluate the impact of the import tariff or the consumption mandate, because the import tariff is so similar in magnitude to the blenders credit. Imported Brazilian ethanol is subject to the 54¢ import tariff but then benefits from the 51¢ blenders credit so these two approximately offset each other. We ignore the ethanol mandate because it was not binding in the base period since high energy prices encouraged ethanol production to grow beyond the ethanol mandate that was in place that year. Also, we have not considered the impact of induced higher prices of other crops. It seems likely that

consumers of these other crops lost and producers gained and loan deficiency payments fell as a result of ethanol subsidies. We also ignore the possible environmental benefits or costs of ethanol production and consumption.

### ***Corn Market***

Consider the standard supply and demand model for corn graphically depicted in figure 1, where  $S_C$  is the supply schedule and  $D_C^{ne}$  represents non-ethanol demand for corn including feed, exports, and other consumption. The equilibrium price and quantity are  $P_C$  and  $Q_C$ , respectively. In this original equilibrium, given the loan rate in the 2002 Farm Security and Rural Investment Act of 2002 (FSRI), corn producers receive a price of  $P_{LR}$  for each bushel of corn produced, yielding a total production of  $Q_{LR}$  bushels, and the market clears at price  $P_0$ . Loan deficiency payments (LDPs) generate producer surplus of  $P_{LR}C'DP_C$ , consumer surplus of  $P_CDB'P_0$ , and taxpayer costs of  $P_{LR}C'B'P_0$ , which add up to a deadweight loss of the area  $C'DB'$ .

Increasing demand for ethanol production pushes up the equilibrium corn price to  $P_C'$ , which is higher than the loan rate  $P_{LR}$ . This higher equilibrium price results in corn production of  $Q_C'$ , while non-ethanol demand drops to  $Q_C''$ . The amount of corn represented by the distance of  $Q_C' - Q_C''$  is used for ethanol production. Under price  $P_C'$ , the total corn demand curve including ethanol is  $D_C'$ . The total gain for the producer is represented by the area  $ACC'P_{LR}$ , while the loss of consumer surplus is the area  $ABB'P_0$ . The taxpayer cost of moving the corn demand curve out is considered within the energy market because it appears in the form of a blenders tax credit. In addition, this

higher equilibrium corn price eliminates LDPs to farmers. The corresponding welfare gain for taxpayers is the shaded area  $P_{LR}C'B'P_0$  in figure 1.<sup>2</sup>

### ***Ethanol, Gasoline, and Transportation Fuel Markets***

The markets for ethanol, gasoline, and fuel are in the left and right panels of figure 2. The horizontal axis is measured in gallons of gasoline equivalent and the vertical axis is measured in the price of gasoline (or fuel) because the energy of 2.66 gallons of ethanol is equivalent to 1.74 gallons of gasoline. That is, we measure the quantity of ethanol in 0.65 gallon units. When we measure the blenders tax credit in energy equivalence, it is equal to 78¢ per gallon. Demand for non-fuel ethanol and total ethanol supply are represented by  $D_e^{nf}$  and  $S_e$ , respectively, which appear in the left panel of figure 2. We assume that U.S. non-fuel ethanol demand is perfectly inelastic because demand for unadulterated ethanol comes primarily from medical uses and is very small, at 380 million gallons in 2007.

In the right panel of figure 2, supply in the gasoline market is given by  $S_g$ . Without the ethanol tax credit  $t$ , equilibrium prices are  $P_e^{nf}$  and  $P_g$  in the two respective markets. Ethanol demand for fuel use is zero at this original equilibrium price. The amount of ethanol that will be supplied for fuel at prices higher than  $P_e^{nf}$  is given by the excess supply curve  $XS_e$ . The 51¢ federal tax credit  $t$  (or 78¢ in the gasoline equivalent unit) has the effect of shifting the demand for ethanol used in fuel to  $D_e^f$ . The intersection of demand and supply curves leads to a new equilibrium ethanol price of  $P_e^f$ , at which the excess supply of ethanol used in fuel is represented by  $FH$  ( $=P_e^f H'$  on the excess supply

curve in the right panel). In the ethanol market, producers' gain is represented by the hatched area  $FP_e^f P_e^{nf} G$ . Consumer surplus does not change because the non-fuel ethanol demand curve is vertical.

We shift down the excess supply curve of ethanol by the amount of the tax credit  $t$  to  $XS_e'$ . The new fuel supply curve is  $S_f$  with the amount of ethanol  $P_f I (=P_e^f H')$  and gasoline  $P_f J$ . The resulting equilibrium fuel price is  $P_f$ . Gasoline use is reduced by the amount of  $JL$ , which is substituted by ethanol, and fuel consumption is increased by the distance of  $LK$  because of the lower price of fuel. In the total fuel demand of  $P_f K$ , the amount of  $JK$  is met by ethanol, which is equal to the amount of  $P_f I$ . Gasoline producers lose the area  $P_g MJP_f$  and fuel consumers gain the area  $P_g MKP_f$ . The net change of consumer and producer surpluses is represented by the hatched area  $MKJ$ . The amount of government payments for the ethanol tax credit is represented by the shaded area  $P_e^f H' IP_f$ . The producer surplus in the ethanol market is the shaded area  $FHG$  in the left panel of figure 2. We assume that the non-fuel ethanol demand is negligible compared with fuel ethanol production.

The total ethanol tax credit  $t$  consists of three components: (1) the reduction in the fuel price because of ethanol substitution denoted by  $P_g - P_f$ ; (2) the price change in the ethanol market,  $P_e^f - P_e^{nf}$ ; and (3) the price difference between  $P_e^{nf}$  and  $P_g$ . The price change of  $P_e^f - P_e^{nf}$  represents the “wasted” portion of the tax credit, which is used to make the ethanol production economically feasible, and is referred to as “water” by de

Gorter and Just. Although qualitative relations exist among these three components, the specific cut-off points vary over time and critically depend on corn and crude oil prices.

## **Welfare Estimates**

Given the annual market data and assumed parameters, as shown in table 1, the net welfare loss in the U.S. corn market is approximately \$2.12 billion, as presented in table 2. The welfare gain from the reduced LDPs for corn is \$3.45 billion according to the average actual payments of 2005 and 2006.<sup>3</sup> The change of producer surplus in the ethanol market is about \$0.86 billion, while the net welfare change before the government cost of the ethanol credit is estimated to be \$0.29 billion in the gasoline/fuel market. Ethanol production in 2007 provided a benefit to corn, ethanol producers, and gasoline/fuel consumers. It reduced welfare for grain consumers and gasoline refiners. The overall net welfare loss is approximately \$0.78 billion.

The basic parameters assumed for U.S. corn and gasoline markets are summarized in table 1. In the corn market, the elasticity of demand is assumed to be -0.15 with range of -0.10 to -0.20, while the elasticity of supply is 0.27 ranging and ranges from 0.13 to 0.40. We take these parameters from Elobeid and Tokgoz.<sup>4</sup> The short-run gasoline elasticity of demand is -0.35 with a range of -0.2 to -0.5 and that of supply is 0.25 varying from 0.1 to 0.4. The elasticity parameters in the gasoline market are based on a survey conducted by Graham and Glaister.

We calibrate the model to 2007 market data of price and production, which are also reported in table 1. There are three important price changes for the welfare analysis: (1) the reduction in the fuel price,  $P_g - P_f$ , which is estimated as \$0.14 in Du and Hayes; (2)

the increase in the corn price,  $P_c^* - P_c$ , which is \$1.27 as reported in Tokgoz et al.; and (3) the price change in the ethanol market,  $P_e^f - P_e^{nf}$ . We use average weekly ethanol prices in Chicago in 2005 and 2007 to proxy  $P_e^f$  and  $P_e^{nf}$ , respectively, which results in an ethanol price change of 27¢ (or 41¢ in gasoline equivalent units). The ethanol weekly prices are obtained from *Ethanol and Renewable Fuel News*.

## Sensitivity Analysis

Gardner and Tyner point out that elasticity assumption is critical for the evaluation of welfare changes since these parameters summarize the price responsiveness to policy interventions. In order to test for the sensitivity of our welfare estimates on these assumptions, we evaluate the overall welfare gains for the given ranges of demand and supply elasticities of corn and gasoline markets. The results are depicted in figures 3 and 4. The net welfare loss varies from \$0.22 billion to \$1.38 billion, as corn demand and supply elasticities vary in the given ranges. Similarly, the net welfare loss is in the range of \$0.21 billion to \$1.36 billion, as elasticities of gasoline change.

It has been established that an ordinary consumer surplus measure requires a restrictive path-independence condition on the utility function and constant marginal utility of income so as to ensure its uniqueness as a money measure (Just, Hueth, and Schmitz, p. 136). Compensating and equivalent variation is the recommended alternative and provides measures related to actual changes in utility. Following the indirect estimation method developed in Willig and in Just, Hueth, and Schmitz (Section 6.5), we calculate the approximate compensating variations in corn and gasoline markets. These

approximations are based on the income elasticities and disposable personal income in 2007 as reported in table 1 and the approximation formula:

$$\widehat{CE} = \Delta CS(1 - \hat{\varepsilon}) \quad \hat{\varepsilon} = \frac{\eta |s|}{2}, \quad s = \frac{\Delta CS}{m}$$

where the compensating variation is denoted by  $CE$ , and  $\Delta CS$  is the change in consumer surplus. Income elasticity of demand is denoted by  $\eta$  while disposable personal income is  $m$ . The approximation results are presented in table 2. Because of the small ratio of surplus change to total disposable income (< 0.01 in both cases) and income elasticity, the difference between two consumer welfare measures is very small. The estimated total net welfare loss based on the compensating variation measure is about \$0.79 billion.

## Conclusion

Government support policies coupled with high energy prices stimulated a rapid increase in ethanol production and associated welfare transfers in multiple markets. We find that the net welfare change of the U.S. ethanol subsidy is negative, a result that is robust with respect to a reasonable range of alternative parameter values. The markets for agricultural commodities were not competitive prior to large-scale ethanol production because there was already significant intervention in the form of farm subsidies. Our results show that subsidizing U.S. ethanol production generated a small aggregate welfare loss while also reducing the distortion associated with farm payments.

## Endnotes

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<sup>1</sup> In this study, fuel refers to gasoline blended with ethanol used for transportation.

<sup>2</sup> Averaged over 2005 and 2006, the LDP for corn is about 81% of total payments.

<sup>3</sup> The actual LDP data are obtained from the CCC Budget Essentials of the Farm Service Agency (FSA) at

<http://www.fsa.usda.gov/FSA/webapp?area=about&subject=landing&topic=bap-bu-cc>, last visited 10/8/2008.

<sup>4</sup> We use the ranges of demand and supply elasticities in the following section to test for sensitivity of the welfare estimates.

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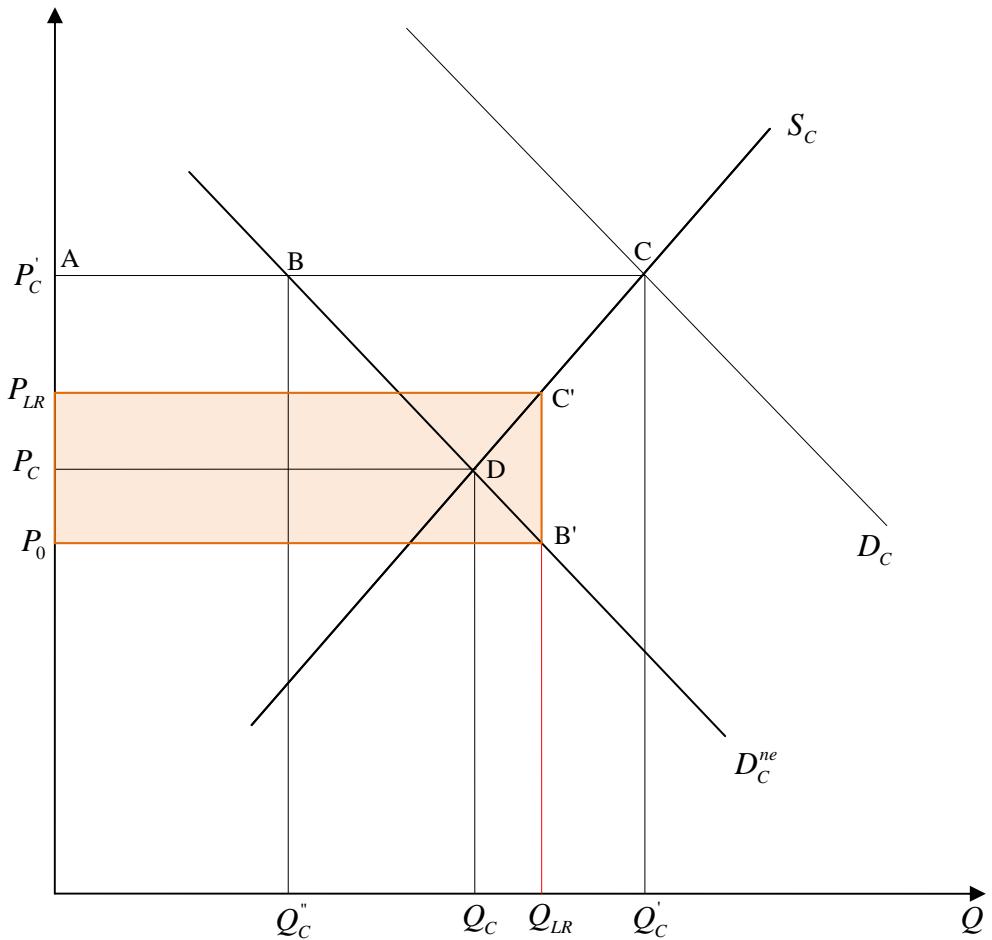
**Table 1. Basic market parameters**

	U.S. Corn Market	U.S. Gasoline Market	U.S. Ethanol Market
Price elasticity in demand	-0.15	-0.35	--
Price elasticity in supply	0.27	0.25	--
Average price, 2007	\$3.40/bu.	\$2.84/gal.	\$2.01/gal.
Total U.S. production, 2007	13 billion bu.	142 billion gal.	6.4 billion gal.
Change in price	\$1.27/bu.	\$0.14/gal.	\$0.27/gal.
Income elasticity of demand	0.1	0.4	--
Disposable personal income, 2007 (billions of dollars)	10,170.41		

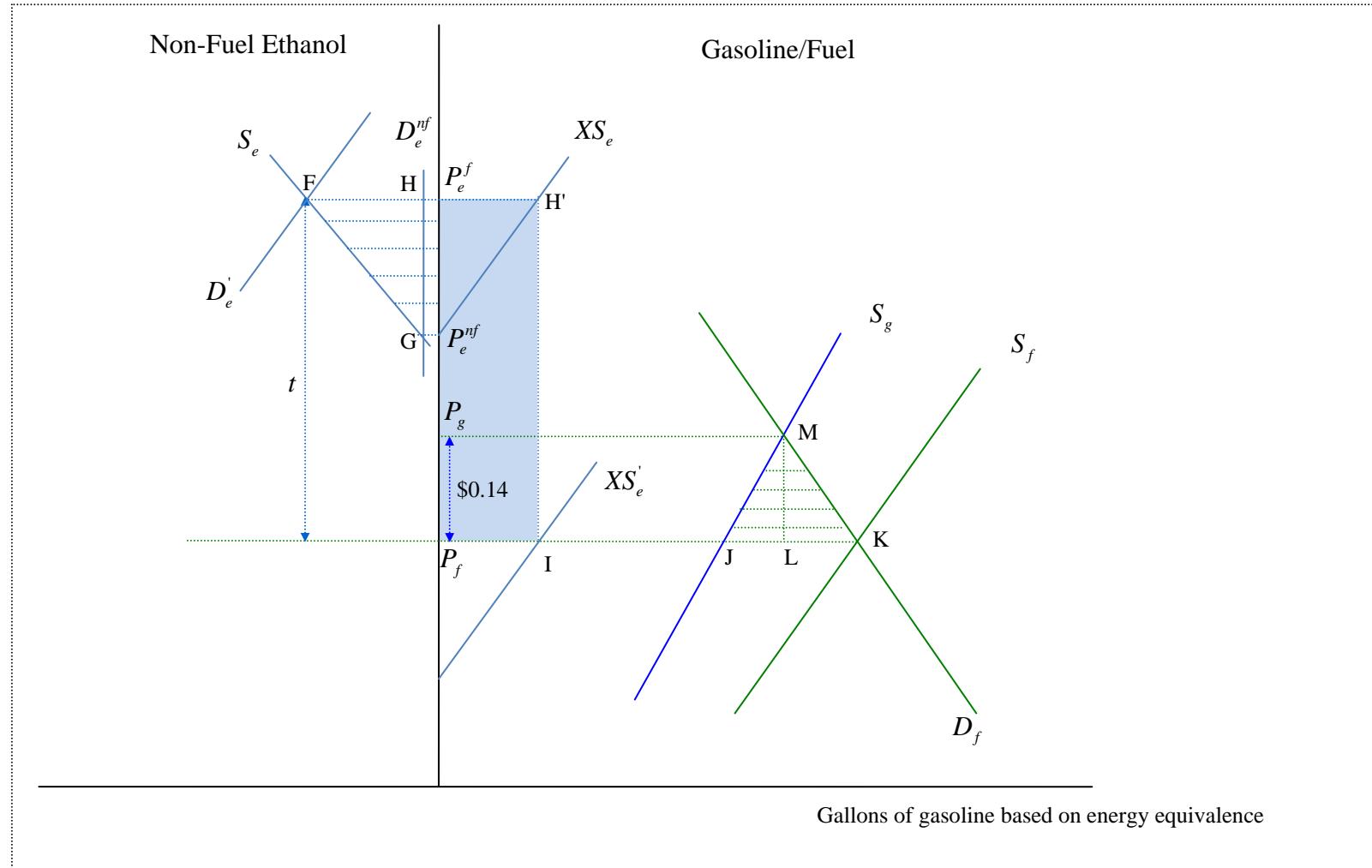
**Table 2. Welfare changes of corn, ethanol, gasoline, and fuel markets in 2007**

<b>Corn market (billion dollars)</b>	
Change in consumer surplus	-16.17
Compensating variation	-16.17
Change in producer surplus	14.05
Change in producer and consumer surpluses	-2.12
Change in CE and producer surplus	-2.12
Reduced LDPs	3.45
<b>Gasoline market (billion dollars)</b>	
Change in consumer surplus	19.71
Compensating variation	19.70
Change in producer surplus	-19.41
Change in producer and consumer surpluses	0.30
Change in CE and producer surplus	0.29
<b>Ethanol market</b>	
Change in producer surplus (billion dollars)	0.86
Volumetric excise tax credit in U.S. (dollars per gallon)	0.51
U.S. taxpayer cost of tax credit (billion dollars)	3.26
<b>Net welfare loss (billion dollars)</b>	
<b>based on CS</b>	0.78
<b>based on CE</b>	0.79

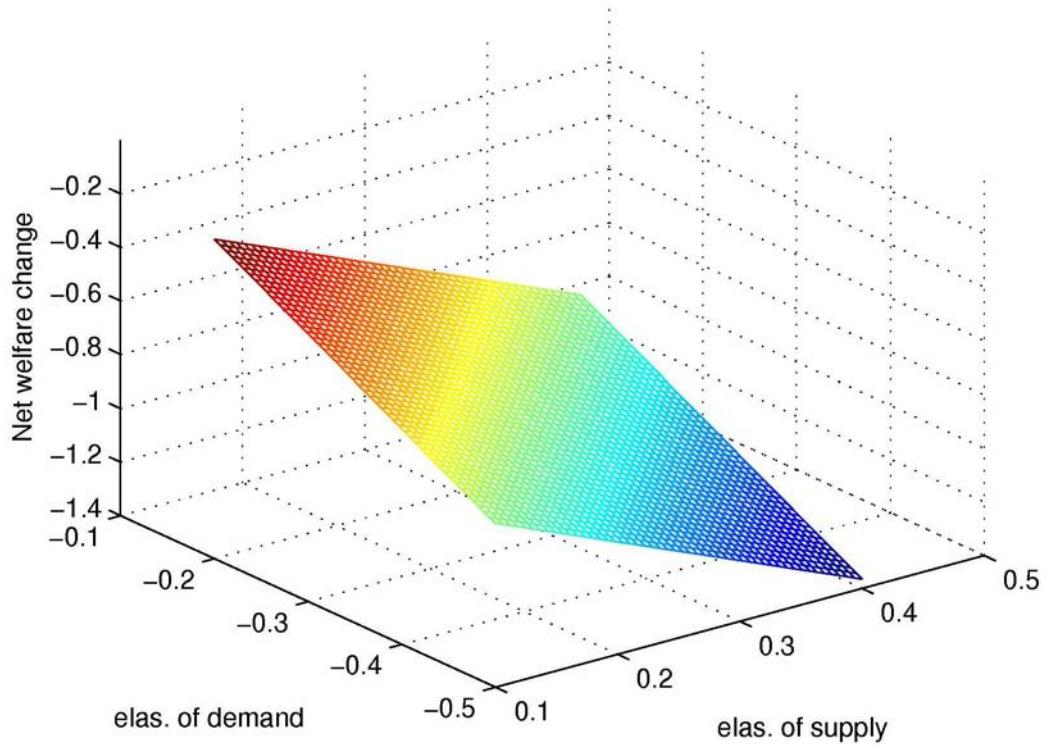
**Figure 1. Corn market**



**Figure 2. Ethanol, gasoline, and transportation fuel markets**



**Figure 3. Net welfare changes for gasoline elasticities**



**Figure 4. Net welfare changes for corn elasticities**

