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Short-Run Price and Welfare Impacts of Federal Ethanol Policies

Lihong Lu Mcphail
Iowa State University, lihong.l.mcphail@gmail.com

Bruce A. Babcock
Iowa State University, babcock@iastate.edu

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Abstract
High commodity prices have increased interest in the impacts of federal ethanol policies. We present a stochastic, short-run structural model of U.S. corn, ethanol, and gasoline markets to estimate the price and welfare impacts of alternative policies on producers and consumers of corn, ethanol, and gasoline. The three federal policies that we consider are the Renewable Fuels Standard, the blenders tax credit, and the tariff on imported ethanol. Our model examines the impact of these policies on prices during the 2008/09 marketing year. Our results show that in the short run, a change in U.S. ethanol policies would not have a large, immediate impact on corn prices. Eliminating any one of the policies would reduce average corn prices by less than 4%. Removal of all three programs would decrease average corn prices by 14.5%. The reason why the changes are relatively modest is that existing U.S. ethanol plants will only shut down if their variable cost of production is not covered. Changes in ethanol policies would have large distributional impacts. Corn growers, ethanol producers, and fuel consumers have a large incentive to maintain high ethanol consumption. Gasoline producers have a large incentive to reduce ethanol production and imports. Livestock producers have a large short-run incentive to reduce domestic ethanol production.

Keywords
ethanol policy, stochastic equilibrium model, welfare analysis

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Lihong Lu McPhail and Bruce A. Babcock

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

Lihong Lu McPhail is a research assistant in the Center for Agricultural and Rural Development (CARD); Bruce Babcock is a professor of economics and director of CARD; both at Iowa State University.

Questions or comments about the contents of this paper should be directed to Bruce Babcock, 578 Heady Hall, Iowa State University, Ames, IA 50011-1070; Ph: (515) 294-6785; Fax: (515) 294-6336; E-mail: babcock@iastate.edu.

Abstract

High commodity prices have increased interest in the impacts of federal ethanol policies. We present a stochastic, short-run structural model of U.S. corn, ethanol, and gasoline markets to estimate the price and welfare impacts of alternative policies on producers and consumers of corn, ethanol, and gasoline. The three federal policies that we consider are the Renewable Fuels Standard, the blenders tax credit, and the tariff on imported ethanol. Our model examines the impact of these policies on prices during the 2008/09 marketing year. Our results show that in the short run, a change in U.S. ethanol policies would not have a large, immediate impact on corn prices. Eliminating any one of the policies would reduce average corn prices by less than 4%. Removal of all three programs would decrease average corn prices by 14.5%. The reason why the changes are relatively modest is that existing U.S. ethanol plants will only shut down if their variable cost of production is not covered. Changes in ethanol policies would have large distributional impacts. Corn growers, ethanol producers, and fuel consumers have a large incentive to maintain high ethanol consumption. Gasoline producers have a large incentive to reduce ethanol production and imports. Livestock producers have a large short-run incentive to reduce domestic ethanol production.

Keywords: ethanol policy, stochastic equilibrium model, welfare analysis.

1 Introduction

The role that U.S. biofuel policies play in determining food prices is a subject of key interest. For example, Governor Rick Perry of Texas has requested a 50% reduction in the mandated use of ethanol because "this misguided mandate is significantly affecting Texans' family food bill."[1] It is understandable why many place the blame for the sharp runup in agricultural commodity prices on U.S. corn ethanol policies. If 25% of U.S. corn is used to create ethanol, then elimination of ethanol could cause corn prices to drop in half. However, this simple calculation provides little insight into the impact that a change in U.S. ethanol policies have on the price of corn, food, and gasoline because U.S. ethanol plants will not simply disappear with a change in U.S. ethanol policies. Plants will keep operating as long as they make more money operating (or lose less) than they would make by shutting down.

The purpose of the paper is to examine the short term impacts of a change in ethanol policies. By short-term we mean the following: What impact would a change in federal policies have on the supply of ethanol and the market price of corn and fuel during the period September 1, 2008 to August 31, 2009? This period corresponds to the marketing year for the 2008 corn and soybean crops. We also estimate the magnitude of the transfers and the associated welfare changes from alternative policies. A focus on corn is warranted because it is the crop most directly affected by U.S. biofuel policies, and it is the crop that most determines the impacts on the cost of food because of its importance in determining the cost of feeding livestock.

The three federal policies we consider are the Renewable Fuels Standard (RFS), the blenders tax credit, and the tariff on imported ethanol. The blenders tax credit is a direct subsidy given to gasoline blenders. The credit increases the willingness of blenders to buy ethanol. This increased demand increases the price of ethanol, ethanol profits, and production, the demand for corn, and the price of corn. The tax credit has greatly stimulated the growth of the industry. The import tariff is a tax on imported ethanol. It has prevented

[1] April 25, 2008, press release from Governor Perry.

the United States. from importing large quantities of ethanol from Brazil except for a short time during 2006 when the phase-out of MTBE caused U.S. ethanol prices to skyrocket. The RFS specifies minimum biofuel consumption levels for the United States. Mandated use rises from 9 billion gallons in 2008 to 10.5 billion gallons in 2009. These mandates can be met from either domestically produced or imported biofuels.

We develop a multi-market, stochastic equilibrium model to simultaneously simulate the price and price volatility of the U.S. corn, ethanol, and fuel for the 2008/09 marketing year. The simulation model is a stochastic version of short-run structural demand and supply models of corn, ethanol, and gasoline markets in the United States. The factors that we treat as stochastic when the model was run (the end of May 2008) are planted acreage, acres not harvested for grain, corn yield, the price of crude oil, export demand, and the capacity of the ethanol industry. Our model attempts to decipher the primary causes of uncertainty in the U.S. corn market in the midst of increasing demand for corn as an energy substitute and new legislation. Our structural model allows us to study the short-run impact of a change in federal biofuel policies, and also easily allows us to analyze the impacts of new information on the price distribution of commodities. McPhail and Babcock (March 2008) simulated the price distribution of corn with information available in early March 2008. The current model run includes updated information released since then, including the U.S. Department of Agriculture (USDA) March "Prospective Plantings" report and the May 2008 World Agricultural Supply and Demand Estimate (WASDE) report. In addition, the model incorporates higher crude oil prices than in March. The present study is the first one to examine the impact of the Energy Independence and Security Act (EISA) mandate on the price variability of corn.

The next section of the paper reviews the previous work. The third section presents the structural model and assumptions used in the present study. The fourth section reports the results of the simulation under different scenarios. The fifth and final section presents conclusions.

2 Previous Work

The existing literature does not report use of a short-run structural model to understand the link between ethanol, energy, and corn. A limited number of studies use long-run structural models to understand the impacts of biofuels. Elobeid et al. (2007) provide the first comprehensive look at the impacts of ethanol on agriculture and the bioeconomy. Later Tokgoz et al. (2007) expand the work of Elobeid et al. (2007) by including work on the equilibrium prices of co-products of the biofuel industries, most importantly distillers grains. Baker et al. (2008) develop a stochastic and dynamic general equilibrium model that captures the uncertain nature of key variables such as crude oil prices and commodity yields and incorporates acreage limitations on key feedstocks.

Few existing studies examine the welfare impacts from a change in current U.S. ethanol policies. Most of the studies focus on the welfare impact of one or two of the policies. Several studies (Gardner 2007, de Gorter and Just 2007a, Schmitz et al. 2007) compare the efficiency of using ethanol subsidies to the efficiency of payment programs for corn farmers. Martinez-Gonzalez et al. (2007) calculate the distortions on U.S. imports from Brazil alone while Kruse et al. (2007) analyze the simultaneous removal of the tax credit and tariff (the mandate is assumed not to be binding). Elobeid and Togkoz (2007) model the elimination of the tariff alone and then the elimination of the tariff and tax credit simultaneously (the possibility of a mandate is not mentioned). de Gorter and Just (2007c) provide a framework to analyze the impact of an ethanol import tariff in conjunction with a consumption mandate and tax credit. Our study enhances the welfare literature by capturing the stochastic nature and providing a distribution of welfare impacts.

The agricultural economics literature contains studies of the impact of government policy on commodity price volatility. Lence and Hayes (2002) used a dynamic three-commodity, rational-expectation model to compare the impact of the Federal Agricultural Improvement and Reform (FAIR) Act of 1996 with a free-market policy, and with the agricultural policies that preceded the FAIR Act, and found that the changes enacted by FAIR did not lead to permanent significant increases in the volatility of farm prices or revenues. The mixed findings of Zulauf and Blue (2003) point to continuing disagreement about government's role in managing farm risk in the post-1996 farm bill world. Isengildina-Massa et al. (2008) used an event study to investigate the impact of USDA WASDE reports on implied volatility in corn and soybean markets over the period 1985-2002 and found that WASDE reports lead to a statistically significant reduction of implied volatility for corn and soybeans. The magnitude of the reduction is largest for the group of WASDE reports containing both domestic and international situation and outlook information. They also found that the market impact of WASDE reports is strongest in the most recent 1996-2002 sub-period. The stochastic model presented in the next section allows us to examine the impact of the EISA mandate on the price volatility of corn.

3 Model Structure and Assumptions

A stochastic equilibrium model is developed to study the impact of the mandate, the tax credit to ethanol blenders, and the ethanol import tariff on the price of corn and the price of fuel. The model solves for equilibrium corn prices, ethanol prices, and gasoline prices in the 2008/09 marketing year. The model is stochastic in the sense that the equilibrium prices depend on the realizations of six random variables. Expectations about price levels and estimates of the price volatility of corn, ethanol, and gasoline can be obtained by solving the model for multiple draws of the random variables and then taking averages and standard deviations of variables across all draws. We assume that random draws are obtained given information available at the end of May 2008. Thus, planted acres, acres not harvested for grain, and yield are all uncertain, which implies that the supply of corn is stochastic. Corn demand is stochastic as well. We consider three random variables that cause demand uncertainty: the position of the export demand curve, crude oil prices, and the capacity of the U.S. corn ethanol industry. Because we do not account for all sources of uncertainty that affect corn prices, our estimated price volatilities should be lower than implied volatilities observed in the market.[2]

3.1 Stochastic Corn Supply in the 2008/09 Marketing Year

Corn supply in the 2008/09 marketing year is determined by planted acreage, the difference between actual planted acreage and acreage harvested for grain, and the yield per harvested acre. Uncertainty in supply comes from uncertain planted acreage, uncertain non-harvested acres, and uncertain yield. Corn prices in 2008 will be affected by harvested acreage and yield in particular because stock levels are relative to use. According to the May WASDE report, U.S. ending stocks for 2008/09 are projected to be 763 million bushels. The demand for corn is strong because of the rapidly expanding consumption of corn used for ethanol production and the strong outlook of export demand due to the low value of the U.S. dollar. Corn supply in 2008 is given by

$$Q^S_{c,t} = (\widetilde{A}_{c,t} - \widetilde{d}_{c,t}) * \widetilde{y}_{c,t} \tag{1}$$

where $Q^S_{c,t}$ denotes the supply of corn, $\widetilde{A}_{c,t}$ is realized planted acreage of corn at time t, $\widetilde{d}_{c,t}$ is the difference between actual planted acreage and acreage harvested for grain, $(\widetilde{A}_{c,t} - \widetilde{d}_{c,t})$ is the harvested acreage of corn at time t, and $y_{c,t}$ is yield per harvested acre We decompose corn supply in this manner because planted acreage is projected by the USDA, but harvested acreage determines actual supply.

Historical yields from 1957 to 2007 are used to estimate the probability distribution of the yield per harvested acre of the 2008 corn crop. We assume that the mean yield of corn per harvested acre follows a linear trend and estimate the percentage deviation in actual corn yields from trend yields from 1957 to 2007.[3] The average percent deviation multiplied

[2] In addition, our estimated price volatilities do not account for the proportion of implied volatilities that generate returns to options traders.

[3] More sophisticated trend models were fit to the yield model, but the 2008 projected trend yield and the estimated percent deviations from trend over the time series differed little from those obtained from a simple

by the 2008 trend yield is used as the standard deviation of national yield. Yield data were obtained from National Agricultural Statistics Service (NASS). The 2008 corn yield is assumed to follow a beta distribution:

$$\widetilde{y}_{c,2008} \sim beta(\overline{y}_{c,2008}, \sigma^2_{y_c}, p_y, q_y) \tag{2}$$

where $\overline{y}_{c,2008} = 151$, $\sigma^2_{y_c} = 194, \max \widetilde{y}_{c,2008} = 177, \min \widetilde{y}_{c,2008} = 113, p_y = 2.43$, and $q_y = 1.66$.Figure 1 shows the resulting distribution.

Yield is independent of planted acreage. A forward-looking, rational farmer decides to plant corn, soybeans, wheat, or other crops to maximize expected profits based on the information set he has about expected prices, yields, and costs of different crops. The farmer's expected profit maximization provides us with information about expected acreage of corn but does not provide information about uncertainty of planted acreage. On March 31, USDA released the "Prospective Plantings" report for 2008. According to the report, corn growers intend to plant 86.0 million acres of corn for all purposes in 2008. We look at the error between the USDA's annual report on prospective planted acreages that are released in March and the actual planted corn acreage to obtain a distribution of corn acreage subject to the March report. The standard deviation of these historical differences is 1.658 million acres. Thus we assume the planted acreage in 2008 (in million acres) follows a normal distribution:

$$\widetilde{A}_{c,2008} \sim N(86, 1.658) \tag{3}$$

The newly released "Prospective Plantings" report not only shows the intentions of farmers but also projects the market price, which may influence the actual planted acreage. We assume that the uncertainty of the distribution based on historical data is able to capture any market response after the release of the report.

linear trend.

The difference between planted acreage and acreage harvested for grain (non-harvested acres) is a function of planted acres, a time trend and the percent deviation in actual corn yields from trend yields. Low national yields means that farmers will choose not to harvest some acres; thus, we expect a negative relationship between non-harvested acres and the deviation in actual yield from predicted yield. NASS data from 1957 to 2007 were used to estimate the relationship The regression equation for non-harvested acres $\widetilde{d}_{c,t}$ (in million acres) is as follows:

$$\widetilde{d}_{c,t} = \widehat{\beta}_0 + \widehat{\beta}_1 * \widetilde{A}_{c,t} + \widehat{\beta}_2 * t + \widehat{\beta}_3 * y^d_{c,t} \tag{4}$$

where $y^d_{c,t} = (\widetilde{y}_{c,t} - \overline{y}_{c,t})/\overline{y}_{c,t}$ is the percent deviation in actual corn yields from trend yields. Table 1 reports the OLS regression results. The standard deviation of the predicted error term is 1.093. We introduce a standard normal error to 2008 U.S. non-harvested acres for corn (in million acres). Thus,

$$\widetilde{d}_{c,2008} = \widehat{\beta}_0 + \widehat{\beta}_1 * \widetilde{A}_{c,2008} + \widehat{\beta}_2 * t + \widehat{\beta}_3 * y^d_{c,2008} + \widetilde{\varepsilon}_{c,2008} \tag{5}$$

where $\widetilde{\varepsilon}_{c,2008} \sim N(0, 1.093)$.

3.2 Corn Demand in the 2008 Marketing Year

Corn demand has five components: food, feed, storage, exports, and the demand from the ethanol industry.

3.2.1 Feed, food, and storage demand

Food, feed, and storage demand are assumed to be nonstochastic. This simplifying assumption will reduce estimated price volatility. The demand curves depend on the average price received by farmers in the 2008/09 marketing year: $Q^{D,feed}_{c,t} = g^{feed}(P_{c,t}); Q^{D,food}_{c,t} = g^{food}(P_{c,t}); Q^{D,\text{storage}}_{c,t} = g^{storage}(P_{c,t})$ where $Q^{D,feed}_{c,t}$ is domestic feed demand of corn at time

t, $Q_{c,t}^{D,food}$ is domestic food demand of corn at time t, and $Q_{c,t}^{D,\text{storage}}$ is the demand of corn from storage; $Q_{c,t}^{D,feed}$, $Q_{c,t}^{D,food}$, and $Q_{c,t}^{D,\text{storage}}$ are linear functions of $P_{c,t}$, the price of corn at time t. Parameters for these demand curves are obtained by assuming a demand elasticity and calibrating to the latest USDA projections in the WASDE on May 9, 2008.[4] The feed demand elasticity is fixed at -0.25. The food demand elasticity is fixed at -0.096. Thus, the feed and food demand curves (in million bushels) in the 2008/09 marketing year are

$$Q_{c,2008}^{D,feed} = 6625 - 240.9 * P_{c,2008} \tag{6}$$

$$Q_{c,2008}^{D,food} = 1490.6 - 23.7 * P_{c,2008} \tag{7}$$

Storage demand elasticity is set equal to -0.65 (FAPRI). WASDE projects that the ending stock for the 2008/09 marketing year is 763 million bushels. We believe that the storage demand cannot be much lower than this amount. Thus the storage demand curve is as follows:

$$Q_{c,2008}^{D,\text{storage}} = \max(763, 1259 - 90.2 * P_{c,2008}) \tag{8}$$

3.2.2 Stochastic export demand

We assume that the export demand uncertainty is mainly due to the uncertainty of the value of the dollar relative to the currencies of the major corn exporting and importing countries and the uncertainty of feed grain production in other countries. Over 2007, the value of the dollar fell against many currencies. A falling dollar makes corn exports look more attractive to importers and therefore increases export demand.

The reduced demand function of corn from export is a function of the cash price

$$Q_{c,t}^{D,\text{export}} = g^{\text{export}}(P_{c,t}, \varepsilon_{c,t}^{D,\text{export}}) \tag{9}$$

[4] http://www.usda.gov/oce/commodity/wasde

where $Q_{c,t}^{D,\text{export}}$ is the export demand of corn, which is a function of $P_{c,t}$ and $\varepsilon_{c,t}^{D,\text{export}}$, a realization of export demand shock. We introduce the export demand shock through the intercept of the demand curve. For simplicity, we use the uncertainty of the dollar to capture the uncertainty of export demand. The average implied volatility for the U.S. dollar index (USDX) option on the New York Board of Trade on March 19, 2008, was approximately 10%.[5] We assume that the short-term export demand elasticity is -0.6 and calibrate the export demand curve based on WASDE. Thus, the export demand curve of corn (in million bushels) in the 2008/09 marketing year is

$$Q_{c,2008}^{D,\text{export}} = 3360 * (1 + 10\% * \varepsilon_{c,2008}^{D,\text{export}}) - 229 * P_{c,2008} \tag{10}$$

where $\varepsilon_{c,2008}^{D,\text{export}} \sim N(0,1)$.

3.2.3 Stochastic demand of corn from ethanol

The demand of corn from the ethanol industry is determined by ethanol production capacity, the percentage of capacity that is in operation, and the number of bushels of corn required to produce a gallon of ethanol:

$$Q_{c,t}^{D,e} = \widetilde{E}_t * \lambda_t * \theta_t \tag{11}$$

where $Q_{c,t}^{D,e}$ is the demand of corn from ethanol, λ_t is the percentage of the ethanol capacity with a nonnegative operating margin, $\widetilde{E}_t$ is the capacity of ethanol production, and θ_t is the number of bushels of corn required to produce a gallon of ethanol.

First, we estimate the distribution of ethanol production capacity, $\widetilde{E}_t$. Keeping track of industry capacity has been a challenge given the explosive growth. Ethanol industry capacity numbers are reported by at least two entities. The lists of plants are given by the Renewable Fuels Association and the American Coalition for Ethanol. These sources suggest that industry capacity at the end of 2007 was around 7 billion gallons. Continued

[5] The USDX is an average of six major world exchange rates and a comprehensive indicator of the dollar's value.

strong growth in capacity coming online is expected in the first half of the 2008/09 marketing year. The rate of new capacity coming online is expected to slow in the second half of the marketing year. Based on information from these resources, we assume that the maximum capacity in the 2008/09 marketing year is 13.5 billion gallons, the minimum capacity is 9 billion gallons, and the average capacity is 11.5 billion gallons. A beta distribution is again used to capture uncertainty (Figure 2):[6]

$$\widetilde{E}_{2008} \sim beta(\overline{E}, \sigma_E^2, p_{E,} q_E) \tag{12}$$

where $\overline{E}_{t+1} = 11.5, \sigma_E^2 = 0.5, \min \widetilde{E}_{t+1} = 9, \max \widetilde{E}_{t+1} = 13.5, p_E = 5, q_E = 4$.

The second demand component is λ_t. Negative processing margins will cause ethanol plants to shut down. Because all plants pay the same price for corn, those plants that produce the least ethanol per bushel of corn processed will tend to shut down first. We denote gallons of ethanol produced per bushel of corn as γ. The distribution of γ determines the proportion of existing capacity that will operate given input and output prices. With a mean of 2.75 gallons per bushel, we assume a maximum efficiency of 2.9 gallons per bushel and a minimum efficiency of 2.5 gallons per bushel. There are no reliable data on which to base plant heterogeneity; thus, we make a reasonable approximation by fixing the variance equal to 0.005. Using a beta distribution again, we specify the distribution of γ as follows:

$$\widetilde{\gamma} \sim beta(\mu_\gamma, \sigma_\gamma^2, p_\gamma, q_\gamma) \tag{13}$$

where $\mu_\gamma = 2.75$, $\sigma_\gamma^2 = 0.005, \underline{\gamma} = 2.5, \overline{\gamma} = 2.9$, $p_\gamma = 4.0625$, and $q_\gamma = 2.4375$. See Figure 3 for a graph of this distribution.

The operating margin per bushel of corn processed for a dry mill ethanol plant is

[6] Capacity for 2008 in the ethanol industry was largely determined before EISA came into force; thus, we assume that the ethanol capacity distribution is exogeneous to the EISA mandate. We also assume that ethanol production capacity is independent of corn and ethanol prices. We don't consider the possibility of stopping before completion of the current expansion when the profit margin cannot cover the annualized fixed cost. The capacity distribution could capture the plants difficulty getting enough credit from banks because of the current bank crisis.

$$\pi_{E,t} = [\gamma * P_{e,t} + D_t * P_{distillers,t}] - (P_{c,t} + \gamma * OPC_t) \tag{14}$$

where $\pi_{E,t}$ is the operating profit margin per bushel, D_t is tons of coproduct distillers grains per bushel, $P_{e,t}$ is the ethanol price per gallon, $P_{distillers,t}$ is the distillers grains price per ton (1 ton equals 2,000 pounds), OPC_t is the operating cost per gallon, $[\gamma * P_{e,t} + D_t * P_{distillers,t}]$ is the revenue per bushel of corn, and $P_{c,t} + \gamma * OPC_t$ is the variable cost per bushel of corn. According to F.O. Lichts (2006), the operating cost for an ethanol plant OPC_t is \$0.54 per gallon. One bushel of corn processed returns 17 pounds of distiller grains; thus, $D_t = \frac{17}{2000}$.

We take the value of the distillers grains as a function of the price of corn. Following Babcock (2008), the relationship between the per ton value of distillers grain and the per bushel price of corn is

$$P_{distillers,t} = 52.5 + 16.406 * P_{c,t} \tag{15}$$

For any ethanol plant, the operating profit margin function can be written

$$\pi_{E,t} = \gamma * (P_{e,t} - 0.54) - 0.860\,55 P_{c,t} + 0.446\,25 \tag{16}$$

For each realization of ethanol price $P_{e,t}$ and corn price $P_{c,t}$, we can calculate the threshold efficiency index $\widehat{\gamma}$ with zero profit:

$$\pi_{E,t} \mid_{\gamma=\widehat{\gamma}} = 0 \tag{17}$$

Thus, ethanol plants with a production efficiency index above $\widehat{\gamma}$ make positive operating profit. Ethanol plants with a production efficiency index below $\widehat{\gamma}$ shut down in the short run. Therefore,

$$\lambda_t(\widetilde{P}_{c,t}, \widetilde{P}_{e,t}, \widetilde{\gamma}) = \Pr(\gamma \geq \widehat{\gamma}) \tag{18}$$

where λ_t is the percentage of the ethanol capacity with a nonnegative operating margin.

The third demand component is θ_t[7], which is the average bushels of corn required to produce a gallon of ethanol for the operating ethanol plants.

$$\theta_t = \frac{1}{E(\gamma \mid \gamma \geq \widehat{\gamma})} \tag{19}$$

Therefore, the demand of corn from ethanol for the 2008/09 marketing year $Q^{D,e}_{c,2008}$ is

$$Q^{D,e}_{c,2008} = \widetilde{E}_{2008} * \lambda_{2008}(\widetilde{P}_{c,2008}, \widetilde{P}_{e,2008}, \widetilde{\gamma}) * \theta_{2008} \tag{20}$$

3.3 Stochastic Ethanol Supply

Ethanol supply is comprised of two parts: the domestic supply and the import supply.

3.3.1 Stochastic ethanol domestic supply

The analysis above also gives us the stochastic domestic supply of ethanol for the 2008/09 marketing year as follows:

$$Q^{DS}_{e,t} = \widetilde{E}_t * \lambda_t(\widetilde{P}_{c,t}, \widetilde{P}_{e,t}, \widetilde{\gamma}) \tag{21}$$

where $Q^{DS}_{e,t}$ is the domestic ethanol supply, which is a function of the percentage of ethanol plants with a nonnegative operating margin λ_t and capacity of ethanol production $\widetilde{E}_t$.

3.3.2 Nonstochastic ethanol import supply

We assume that the ethanol import supply is determined primarily by U.S. trade policy on ethanol, the price difference between U.S. ethanol and world ethanol, transportation cost, and the size of the ethanol sector in other countries (primarily Brazil). U.S. trade policy on ethanol includes an ad valorem tariff of 2.5 % as well as an import duty of $0.54 per gallon. One motivation for this tariff is to ensure that the benefits of the current domestic

[7] For our simulation, we set $\theta_t = 1/2.75$ for simplicity.

U.S. ethanol tax credit of $0.51-per-gallon do not accrue to foreign producers, although this rationale has been weakened by the recent reduction in the tax credit, which was not accompanied by an equivalent reduction in the tariff. The Caribbean Basin Initiative (CBI) is the other important trade policy for ethanol, under which duty-free status is granted to ethanol from the beneficiary countries[8] under certain conditions. If ethanol is produced from at least 50% local feedstock (e.g., sugarcane grown in CBI beneficiary countries), it is admitted into the U.S. free of duty. If the local feedstock content is lower, limitations apply on the quantity of duty-free ethanol. Nevertheless, up to 7% of the U.S. market may be supplied duty-free by CBI ethanol containing no local feedstock. To comply with this requirement, hydrous (wet) ethanol produced from non-CBI countries can be imported to a CBI country for dehydration and then be exported to the U.S. after it is rehydrated in a CBI country. The difference between U.S. and world ethanol prices is an important indicator of the competitiveness of U.S. versus others countries' ethanol sectors. For example, if we see a large increase in the price difference between U.S. and world ethanol, we could expect an increase in ethanol imported from Brazil. However, the renewable fuel mandate in Brazil reduces the elasticity of ethanol supply from Brazil. There are no reliable data on which to estimate the supply of imports from Brazil. We assume that the ethanol import supply will be 1.6 billion gallons if exporters make 40 cents per gallon more in the U.S. than they would in Brazil after paying transportation costs and any tariff. We also assume that the ethanol import supply will be 800 million gallons if exporters make the same in the U.S. as they do in Brazil after transportation and tariff costs. Based on these beliefs, we can only make reasonable approximations of the linear import supply (in billion gallons) as follows:

$$Q^{IS}_{e,t} = \max(0, 0.8 + 2 * (\widetilde{P}_{e,t} - \widetilde{P}^{Br}_{e} - TC_e - t_m)) \quad (22)$$

[8] The beneficiary countries are those named under the Caribbean Basin Economic Recovery Act (CBERA), which include Central American countries and Caribbean countries.

where $Q^{IS}_{e,t}$ is the ethanol import supply, $\widetilde{P}^{Br}_{e}$ is the ethanol price in Brazil, TC_e is the cost of transporting a gallon of ethanol from Brazil to the U.S. and t_m is the import duty and tariff. We do not intend to model the Brazil ethanol market; thus, we assume that $\widetilde{P}^{Br}_{e} = 0.66\widetilde{P}_{g,t}$ for approximation, where $\widetilde{P}_{g,t}$ is the gasoline price in the U.S.. We also assume that $TC_e = \$0.18$ per gallon and $t_m = \$0.6$ per gallon.[9] Thus, $Q^{IS}_{e,t} = \max(0, 0.8 + 2 * (\widetilde{P}_{e,t} - 0.66\widetilde{P}_{g,t} - 0.18 - t_m))$.

Thus, the total supply of ethanol for the 2008/09 marketing year is

$$Q^{S}_{e,t} = Q^{DS}_{e,t} + Q^{IS}_{e,t} \tag{23}$$

where $Q^{S}_{e,t}$ is the total supply of ethanol.

3.4 Stochastic Ethanol Demand

We calibrated the first segment of the demand for ethanol $(1d)$ based on the following assumptions. We believe that ethanol demand is very inelastic up to 4 billion gallons, because ethanol's use is mandated for some regions of the country that must meet clean air standards and because ethanol is the best source of octane in gasoline blends. We assume the demand for ethanol will be more than 4 billion gallons as long as the price of ethanol relative to that of gasoline is less than 1.1. In this segment of the demand curve, the demand elasticity is -0.06 following FAPRI. We calibrated the second segment of the ethanol demand curve $(2d)$ to the price and demand data for the 2007/08 marketing year. Fuel blenders say that they use one gallon of ethanol to replace one gallon of gasoline and will continue to do this up to about 14 billion gallons, but we know that transportation bottlenecks create a lower willingness to pay for ethanol below its intrinsic value in a fuel blend. Although we might expect to see ethanol selling above its energy value for aggregate ethanol volumes in the range of 10 to 14 billion gallons per year, transportation bottlenecks that need to be overcome in delivering ethanol to population centers have tended to reduce prices. Eventually, ethanol

[9] According to U.S. trade policy, $t_m = 2.5\% * \widetilde{P}_{e,t} + 0.54$. Thus, $Q^{IS}_{e,t} = 800 + 2000 * (\widetilde{P}_{e,t} - 0.66\widetilde{P}_{g,t} - 0.18 - 2.5\% * \widetilde{P}_{e,t} - 0.54) = 800 + 2000 * ((1 - t_m\%)\widetilde{P}_{e,t} - 0.66\widetilde{P}_{g,t} - 0.18 - t_m\$)$.

will be valued by its energy value. Because ethanol has approximately 67.8% of the energy content of gasoline, the conventional wisdom is that blenders' maximum willingness to pay for ethanol as a substitute fuel source is 67.8% of the price of gasoline, as consumers will not pay more than this amount because of lower mileage performance in their automobiles. Thus, it seems likely that owners of flex-fuel vehicles in the U.S. will not use E-85 unless it is priced to reflect its lower energy content. But if there are adequate numbers of E-85 vehicles or if the United States moves to allow ethanol blends in excess of E-10, then all gasoline consumers will have an incentive to use ethanol blends if the price of the blend is low enough. This suggests a quite elastic demand for ethanol as a substitute for gasoline at increased quantities of ethanol. We assume that the third segment of the ethanol demand curve ($3d$) is perfectly elastic given the gasoline price. Therefore the demand curves of ethanol (in billion gallons) in the 2008/09 marketing year are

$$(1d)\ Q^D_{e,t} = 4.22 - 0.2 * (\frac{\widetilde{P}_{e,t} - tc_e}{\widetilde{P}_{g,t}})\ \forall Q^D_{e,t} < 4\ \&\ \frac{\widetilde{P}_{e,t} - tc_e}{\widetilde{P}_{g,t}} > 1.1 \tag{24}$$

$$\begin{aligned}(2d)\ Q^D_{e,t} &= 13.625 - 8.75 * (\frac{\widetilde{P}_{e,t} - tc_e}{\widetilde{P}_{g,t}}) \\ \forall Q^D_{e,t} &\in [4, 7.7)\ \&\ \frac{\widetilde{P}_{e,t} - tc_e}{\widetilde{P}_{g,t}} \in (0.6781, 1.1]\end{aligned} \tag{25}$$

$$(3d)\ Q^D_{e,t} = Q^S_{Ethanol,t}\ \&\ \frac{\widetilde{P}_{ethanol,t} - tc_e}{\widetilde{P}_{gas,t}} = 0.6781 \forall Q^D_{Ethanol,t} \geq 7.7 \tag{26}$$

where $Q^D_{e,t}$ is the demand of ethanol, tc_e is the tax credit to the ethanol blenders,[10] and $Q^D_{g,t}$ is the demand of gasoline.

[10] The blenders tax credit does not go down to 45 cents until Jan. 1, 2009. So there are four months at 51 cents and 8 months at 45 cents. Thus we use a 47 cents blenders tax credit in our simulation.

3.5 Stochastic Fuel Demand

The demand for transportation fuel (gasoline blended with ethanol) depends on the weighted price of fuel: $Q^D_{f,t} = f(\widetilde{P}_{f,t})$, where $\widetilde{P}_{f,t} = \alpha * \widetilde{P}_{e,t} + (1-\alpha) * \widetilde{P}_{g,t}$, $Q^D_{f,t} = 0.6781 * Q^D_{e,t} + Q^D_{g,t}$ and $\alpha = \frac{Q^*_{e,t}}{Q^*_{e,t}+Q^*_{g,t}}$. Ethanol as a substitute for gasoline will reduce the demand for gasoline. However, a lower ethanol price will reduce the blended fuel price, thus increasing the demand for fuel and the demand for gasoline. So the net effect of ethanol on the demand and the price of gasoline depends on both the substitution effect and the income effect. The blended fuel demand curve can be calibrated to the demand and price data of gasoline and ethanol of the Energy Information Administration's (EIA) short-term energy and summer fuel outlook in the 2007/08 marketing year. In this outlook the average refiner price of gasoline for resale (CBOB) for the 2007/08 marketing year is \$2.62 per gallon. The average rack price for ethanol for the 2007/08 marketing year is \$2.36 per gallon. The demand for motor gasoline for the 2007/08 marketing year is 142.7 billion gallons (including the demand for ethanol). The demand for ethanol for the 2007/2008 marketing year is 7.4 billion gallons. Adjusting for the energy value of ethanol, the demand is 139.6 billion gallons. We use the price of gasoline from the EIA short-term energy and summer fuel outlook and the price of ethanol from the futures market to calculate a weighted average price of composite fuel of \$2.6 per gallon. We assume that the short-run price elasticity of gasoline demand is -0.1. We introduce a 1.5% annual increase of fuel consumption. Thus, the fuel demand curve (in billion gallons) for the 2008/09 marketing year is

$$Q^D_{f,t} = 155.86 - 5.45 * \widetilde{P}_{f,t} \tag{27}$$

The gasoline demand (in billion gallons) for the 2008/09 marketing year is

$$Q^D_{g,t} = Q^D_{f,t} - 0.6781 * Q^D_{e,t}$$

3.6 Stochastic Gasoline Supply

3.6.1 Domestic gasoline supply

In the long run, the growth in biofuels affects both the mix and volume of new refinery capacity that is needed. However, in the short run the U.S. refinery capacity is fixed. Thus, the growth of biofuels only affects the mix of refinery capacity. According to Robert Pore,[11] the price of gasoline isn't rising as quickly as the price of diesel, partly because expansion of ethanol is adding effective refining capacity. Thus, the growth of ethanol is squeezing the profit margin of refineries.

We consider a refinery production unit employing inputs (e.g., crude oil) to produce a mix of outputs (e.g., gasoline, distillate fuels, and jet fuel). We assume that U.S. refineries take output prices and input prices as given and attempt to adjust the optimal mix of outputs to maximize profits. The profit-maximizing gasoline supply is a function of the relative price of gasoline to distillate fuels and the relative price of gasoline to crude oil. As the focus of this model is the gasoline market, we assume that the domestic gasoline supply is a function of the relative price of gasoline to crude oil for simplicity. We assume that the short-run price elasticity of the gasoline supply is 0.4. The gasoline supply curve is calibrated to the April supply and price data of EIA's short-term energy and summer fuel outlook in the 2007/08 marketing year. The domestic gasoline supply is 120 billion gallons for the 2007/08 marketing year. In this outlook, the average wholesale gasoline price is $2.62 per gallon and the average crude oil price is $96.83 per barrel for the 2007/08 marketing year. Thus, the gasoline supply curve (in billion gallons) for the 2008/09 year is

$$Q_{g,t}^{DS} = 72 + 1774 * (\widetilde{P}_{g,t} / \widetilde{P}_{crude,t}) \tag{28}$$

The price of crude oil is exogenous and follows a lognormal distribution. The mean price of crude oil is $130 per barrel, which is the average of the futures price of crude oil from

[11] Robert Pore, "Ethanol saving drivers $5M per month," http://www.theindependent.com/.

September 2008 to August 2009 on the NYMEX on May 21, 2008. The volatility of the crude oil price is 32%, which is the implied volatility of the August 2009 crude oil futures option on the NYMEX on May 21, 2008. Thus, the standard deviation is 41.6%.

3.6.2 Gasoline import supply

We assume the gasoline import supply to be 15.9 billion gallons for the 2008/09 marketing year based on the EIA's short-term energy and summer fuel outlook, which means, that $Q^{IS}_{g,t} = 15.1$.[12]Thus, the total gasoline supply $Q^{S}_{g,t}$ is

$$Q^{S}_{g,t} = Q^{DS}_{g,t} + Q^{IS}_{g,t} \tag{29}$$

3.7 Equilibrium in the Corn, Ethanol, and Fuel Markets

For each realization of yield, acreage, non-harvested acreage, export, ethanol production capacity, and gas price, we will have one realization of the equilibrium corn price at which the corn market clears:

$$Q^{S}_{c,t} + Q^{D,storage}_{c,t-1} = Q^{D,feed}_{c,t} + Q^{D,food}_{c,t} + Q^{D,storage}_{c,t} + Q^{D,export}_{c,t} + Q^{D,ethanol}_{c,t} \tag{30}$$

where $Q^{D,\text{storage}}_{c,t-1}$ is the beginning stock of corn at time t, which is the demand of corn from storage at time $t-1$.

[12]The U.S. has been a good market for Europe's excess gasoline. Europe's concerns over greenhouse gas emissions have resulted in policies to reduce energy consumption by shifting less efficient gasoline-fueled vehicles to more efficient diesel-fueled vehicles. This has resulted in diesel fuel demand increasing and gasoline demand falling. The diesel and gasoline demand trends have resulted in Europe needing increasing distillate imports and generating increasing volumes of gasoline for export. European gasoline exports have increased by 505,000 barrels per day from 1999 to 2006, and U.S. imports have increased 520,000 barrels per day over the same period. Europe's interest in biofuels to help reduce greenhouse gas emissions has focused on biodiesel and ethanol. Ethanol use in Europe's gasoline will add to its export volumes. U.S. refiners will potentially see increased export volumes of gasoline available from Europe both because of Europe's continued gasoline demand decline and potentially because of increased ethanol use in Europe. We use monthly data from Jan. 2004 to Feb. 2008 from EIA and run a regression of net imports (which includes both finished motor gasoline imports and blending components net imports from all countries) on the price spread between the New York Harbor Conventional Gasoline regular spot price and the Amsterdam-Rotterdam-Antwerp (ARA) 10ppm Conventional Gasoline regular spot price, a time trend, a summer dummy, and a hurricane dummy. However, we find the price spread is not statistically significant after controlling for the other variables.

Also, we will have one realization of the equilibrium ethanol price at which the ethanol market clears:

$$Q_{e,t}^{D} = Q_{e,t}^{DS} + Q_{e,t}^{IS} \tag{31}$$

where we don't consider the ethanol export and stock, as the levels are very low compared to the total demand. With the mandate in place, $Q_{e,t}^{D} \geq 10$ billion gallons. If the mandate binds, then we solve for the price of ethanol that induces enough plants to produce 10 billion gallons. The difference between the market price of ethanol when the mandate binds and when the mandate does not bind (at the same draws of all random variables) is the value of the renewable identification number (RIN) for that draw.

The clearing condition for the gasoline market is

$$Q_{f,t}^{D} - 0.6781 * Q_{Ethanol,t}^{D} = Q_{g,t}^{S} \tag{32}$$

4 Results

We simulate the short-term corn, ethanol, and gasoline market equilibriums for the 2008/09 marketing year under different policy scenarios. Table 2 presents the price, demand, and supply results for all the scenarios. We also estimate the associated consumer and producer surplus change, for all parties involved, from a policy change. The change in consumer surplus for domestic feeders, corn importers, food users, ethanol blenders,[13] and fuel users[14] can be easily estimated by using the demand curves. The change in producer surplus for the gasoline producers and ethanol exporters can be estimated by using their supply curves. The change in producer surplus for corn growers is equal to the change in average revenue, as producer surplus can be measured by profits, and costs of producing corn are constant across

[13]The consumer surplus of ethanol blenders (the area under the blenders' ethanol demand curve) measures the net benefit of blending ethanol to meet performance requirements and clean air standards.

[14]The consumer surplus of using ethanol as a substitute for fuel is captured by the fuel demand curve.

the scenarios given in our model. The change in producer surplus for ethanol producers can be measured by the change in the quasi-rent to ethanol producers because we do not model 2008/09 production capacity as a function of the price of ethanol.[15] Table 3 presents the welfare impacts in a change of federal biofuel policies. Please note that our welfare estimates do not assign a value to any externalities associated with ethanol production, such as a change in greenhouse gas emissions or fuel supply security.

We establish a baseline against which we can compare different scenarios with a change of current biofuel policies. The baseline includes current ethanol mandates, \$0.47-per-gallon tax credits, and import tariffs. The new RFS in EISA requires 9 billion gallons of corn-based ethanol in 2008 and 10.5 billion gallons in 2009. With two-thirds of the 2008/09 marketing year in 2009, this translates into a requirement of 10 billion gallons for the marketing year. The Environmental Protection Agency (EPA) is responsible for promulgating regulations to ensure that gasoline sold in the U.S. contains a minimum volume of renewable fuel. The EPA announced that 9 billion gallons of renewable fuels are going to be required to meet the 7.76% RFS on February 14, 2008. This requirement applies to refiners, importers, and certain blenders of gasoline. Each obligated party determines the volume of renewable fuel that it must use based on the standard.[16] The EPA developed a credit trading program to enable universal compliance. To determine RINs, the EPA determined "equivalence values" based on the fuels' energy content in comparison to the energy content of ethanol and adjusted as necessary for their renewable content. A RIN is a gallon of corn-based ethanol. The system requires that a RIN be issued with each shipment of biofuel. Blenders can use the RIN for their own compliance as well as trade or sell excess RINs to others through the RIN Exchange.[17] The market price of RIN is the difference between the demand and supply prices of ethanol. The price of RIN is positive only when the mandate is binding.

[15] The quasi-rent to ethanol producers=$(P_{e,t} - 0.54) * Q_{e,t}^{DS} - Q_{c,t}^{D} * [P_{c,t} - \frac{17}{2000} * (52.5 + 16.404 * P_{c,t})]$.

[16] The standard is calculated as a percentage, by dividing the amount of renewable fuel that the act requires to be blended into gasoline for a given year by the amount of gasoline expected to be used during that year. The Clean Air Act, as amended by the Energy Independence and Security Act of 2007 (EISA), requires the EPA to annually determine an RFS.

[17] http://www.rinxchange.com/

In the baseline we assume that the distribution of stochastic variables in our model is obtained given information available at the end of May 2008. Crude oil price levels and price variability are taken from the New York Mercantile Exchange "light sweet crude oil" futures and options markets. We calibrate the structural model for corn and fuel markets to the May WASDE and the April EIA shortterm energy and summer fuel outlook.

For the 2008/09 marketing year,our baseline corn price distribution has a mean (the expected price) of \$5.86 per bushel and a volatility of 31.26%. The average ethanol, gasoline (CBOB), and blended fuel prices would be \$2.69, \$3.11, and \$3.08 per gallon, respectively. On average, 92% of ethanol domestic production capacity would be operating. The average domestic ethanol production, ethanol import supply, and ethanol blended would be 10.62 billion, 506 million, and 11 billion gallons, respectively. The expected total gasoline supply (both domestic and import) and the expected total fuel demand (adjusted by energy content) would be 131.6 billion and 139.1 billion gallons, respectively. The probability that the mandate is binding would be 28%. The RIN price distribution has a mean of 9.6 cents per gallon with a standard deviation of 21 cents per gallon.

4.1 Mandate Elimination

A relaxation of mandates would have little impact on the ethanol industry's capacity unless some plants currently under construction are mothballed. The 2008 crop-year impacts of eliminating the mandate are modest. Because both the blenders tax credit and the mandate increase the demand for ethanol, elimination of only one of these policies would have little impact because the other one would effectively keep the industry operating at close to current capacity. We estimate that such a policy change would decrease the expected corn price by 3.9%, to \$5.63 per bushel. The corn price volatility would decrease to 29.3% because corn prices are not bid up as strongly without a mandate in short-crop years. Elimination of the mandate would reduce expected ethanol production by about 3%; the ethanol price would drop by less than 3%; imports would fall by 34.8%; the gasoline supply would decrease by

0.2%; total ethanol use would drop by 4.4%; and the fuel price would increase by 0.3%. On average, 90% of ethanol domestic production capacity would be operating.

On average, elimination of the EISA mandate would reduce the welfare of corn growers, ethanol producers, ethanol exporters to the U.S., and fuel users while increasing the welfare of domestic feeders, food users, corn importers from the U.S., ethanol blenders, gasoline producers, and taxpayers. Corn growers would be the biggest loser, with an estimated expected producer surplus loss of $2.37 billion. Domestic fuel users would lose an expected consumer surplus of $1.45 billion. On average, the producer surplus loss of ethanol producers and ethanol exporters would be $54 million and $84 million, respectively. Gasoline producers would be the biggest winner, with an estimated expected producer surplus gain of $1.88 billion, and domestic livestock feeders would be the second-largest winners, with an estimated expected producer surplus of $1.12 billion. On average, ethanol blenders, corn importers from the U.S., and domestic food users would gain $940 million, $435 million and $303 million in consumer surplus, respectively. U.S. government revenue would increase by $126 million. We see welfare transfers from corn growers to corn users and from fuel users to gasoline producers. The expected net welfare gains from eliminating the EISA mandate would be $846 million.

4.2 Tax Credit Elimination

Removing only the blenders credit but leaving the mandate in place would have modest market impacts because the mandate would keep ethanol production high. Taxpayers would benefit because of an increase in tax revenue. But fuel users would have to pay a higher price for ethanol. Corn prices would drop by an average of 3.5% from the baseline level. Expected ethanol production would drop by about 2.8%; the ethanol price would drop by 10.2%; imports would fall by 40.5%; the gasoline supply would increase by 0.2%; the fuel price would increase by 0.1%; and total fuel demand would remain largely unchanged. On average, 90% of ethanol domestic production capacity would be operating. The probability that the mandate is binding would be 49.3%.

On average, removal of the tax credit would reduce the welfare of corn growers, ethanol blenders, ethanol producers, ethanol exporters, and fuel users. It would increase government revenue and the welfare of domestic feeders, food users, corn importers, and gasoline producers. Such a policy change would increase expected government revenue by an average of \$5.1 billion. Gasoline producers would gain \$2.75 billion because of less competition from ethanol production. Domestic feeders, food users, and corn importers from the U.S. would gain about \$1.06 billion, \$275 million, and \$410 million, respectively. Corn growers and ethanol producers would be the top two losers, each with estimated expected losses of \$2.4 billion. On average, ethanol blenders would lose \$909 million and ethanol exporters would lose only \$16 million, as the mandate keeps the ethanol price high. The expected net welfare gain from removing the tax credit would be \$3.46 billion.

4.3 Tariff Elimination

Removing the import tariff while keeping in place the mandate and tax credit creates a large incentive to import ethanol. In this scenario, ethanol imports would more than triple. This surge in imports would reduce domestic ethanol production by an average of 1.9%, which would reduce the price of corn by an average of 2.5%. Ethanol prices would drop by 2.5% and fuel prices would drop by 1.2%. On average, 90% of ethanol domestic production capacity would be operating. The probability that the mandate is binding would be 18.7%.

Removal of the tariff would reduce government revenue, and the welfare of corn growers, and ethanol and gasoline producers, while it would increase the welfare of domestic feeders, food users, corn importers, ethanol blenders, ethanol exporters, and fuel users. Fuel users would benefit most, with an average gain of \$5.08 billion in consumer surplus. On average, domestic feeders, food users, corn importers, and ethanol blenders would gain \$730 million, \$197 million, \$276 million and \$453 million in consumer surplus, respectively. Gasoline producers, corn growers and U.S. ethanol producers would lose \$3.53 billion, \$1.58 billion, and $229 million, respectively. Expected government revenue would decrease by $1.39 billion. The net expected welfare gain on average would be $568 million, which is close to the producer surplus increase of ethanol exporters.

4.4 Tax Credit and Tariff Elimination

Removal of the tax credit and the tariff would result in a substantial but smaller surge in imports, as increased imports would reduce the amount of domestic ethanol that would be needed to meet the mandate. Compared to the baseline results, domestic ethanol production would fall by about 6.1%, imports would increase by 88%, the price of corn would drop by 7.7%, the price of ethanol would drop by 13.7%, and the price of fuel would drop by 0.5%. The probability that the mandate is binding would be 42.3%. The market price impacts of this policy change are not any larger because the RFS keeps total ethanol demand high and the supply of imported ethanol is not unlimited.

Removal of both the tax credit and the tariff would reduce producer surplus of corn growers by $5.16 billion and the producer surplus of ethanol producers by $2.58 billion. The expected consumer surplus of ethanol blenders would decrease by $44 million. Domestic feeders, fuel users, corn importers, and food users would gain by $2.3 billion, $2 billion, $891 million, and $608 million in expected consumer surplus, respectively. The expected government revenue would increase by $4.9 billion. The expected net welfare gain from such a policy change would be $4.88 billion.

4.5 Mandate and Tariff Elimination

Elimination of both the mandate and the tariff would reduce the expected corn price by 4.9% from the baseline level, expected ethanol production would drop by about 3.8%, the expected ethanol price would drop by 4.2%, ethanol imports would increase by 197.8%, the gasoline supply would fall by 0.2%, the fuel price would fall by 1%, and the total fuel demand would increase by 0.1%. On average, 89% of ethanol domestic production capacity would be operating.

Removal of both the mandate and the tariff would reduce the producer surplus of corn growers by about $3 billion, the ethanol producer surplus by $251 million, and the gasoline producer surplus by about $2.4 billion. Government revenue would drop by about $1.2 billion. Fuel users, domestic feeders, ethanol blenders, corn importers, and food users would gain $4.2 billion, $1.4 billion, $1 billion, $551 million, and $382 million in consumer surplus, respectively. Ethanol exporters would gain $454 million in producer surplus. The average net welfare gain from removing both the mandate and the tariff would be $1.2 billion.

4.6 Mandate and Tax Credit Elimination

Removal of both the mandate and the tax credit would have a much larger impact on corn prices because the ethanol industry's ability to pay for corn would decrease substantially. However, the extent to which ethanol prices would fall depends on gasoline prices and on the willingness of blenders to pay for reduced volumes of ethanol. Under this scenario, we estimate that ethanol production would decrease by about 10.3% from baseline levels; the expected ethanol price would decrease by 17.3%; the expected corn price would drop by 13%; and the expected fuel price would increase by 0.9%. The impacts of eliminating the mandate and the tax credit are not as great as one might expect because the ethanol industry would continue to operate until processing margins turn negative. We estimate that the drop in ethanol supply would increase blended fuel prices by about two cents per gallon because increased gasoline prices would more than offset the reduction in ethanol prices. The corn price impacts would be greater if the tariff on imported Brazilian ethanol were also eliminated.

The biggest winner from removal of the mandate and the tax credit would be gasoline producers, who would gain $6.9 billion on average. Government revenue would increase by an average of $5 billion. Domestic feeders, corn importers, food users, and ethanol blenders would gain $3.9 billion, $1.52 billion, $1 billion, and $1.46 billion in expected consumer surplus, respectively. Fuel users would lose $3.75 billion in expected consumer surplus. Corn growers, U.S. ethanol producers, and ethanol exporters would lose $8.4 billion, $2.58 billion, and $112 million in producer surplus, respectively. The average net welfare gain would be about $5 billion.

4.7 All Programs Eliminated

A rollback of all ethanol incentives and protections would have the largest impacts. The expected price of corn would drop by almost 14.5% from the baseline level, to about $5.00 per bushel. The loss of demand subsidies would cause the price of ethanol to drop by 18.6%. The expected fuel price would increase by 0.2%; domestic ethanol production would drop by 11.5%; ethanol imports would increase by 28.1%; total gasoline supply would increase by 0.5%; and total fuel demand would remain almost unchanged from baseline levels. On average, 82% of ethanol plants would be operating in this scenario.

The average net welfare gain from removing all ethanol policies would be $5.8 billion. The expected producer surplus of the biggest winner, gasoline suppliers, would increase by $5.05 billion. Average government revenue would increase by $4.9 billion. Domestic feeders, corn importers, and food users would gain $4.37 billion, $1.72 billion, and $1.14 billion in expected consumer surplus, respectively. The average producer surplus of ethanol exporters would remain almost unchanged. Corn growers and ethanol producers would lose $9.4 billion and $2.65 billion in average producer surplus, respectively. Fuel users would lose $975 million in average consumer surplus.

5 Conclusions

We use a short-run, stochastic equilibrium model to explore the price and welfare impacts of U.S. ethanol policy for the 2008/09 corn marketing year. Policy changes are estimated relative to a baseline policy that includes EISA ethanol mandates, the current blenders tax credit, and current import tariffs. Impacts on the average market prices of corn, ethanol, and gasoline from partial and complete removal of these three policy instruments are estimated, and changes in average producer surplus, consumer surplus, and government revenue are estimated.

Our results show that in the short-run, a change in U.S. policy would not have a large, immediate impact on corn prices, because ethanol plants will keep operating as long as their revenue covers their operating cost. Elimination of any one of the three policies would reduce the average corn price by less than 4%. Removal of any two of the three policies would have a larger but still modest impact on corn prices. For example, the average corn price would drop by 13% if both the mandate and tax credit were removed. A rollback of all ethanol incentives and protections would decrease the expected corn price by 14.5%.

A change in ethanol policies would also affect the price that consumers pay for transportation fuel. Elimination of both the mandate and tax credit would increase the expected blended fuel price by 0.9%. This would reduce fuel users' consumer surplus by $3.7 billion. Fuel users' surplus would increase by more than $5 billion if all tariffs were removed on imported ethanol. Increased competition from imported ethanol would cause both gasoline and ethanol prices to decrease, resulting in a $3.5 billion loss to gasoline producers and a $2.6 billion loss in surplus to domestic ethanol producers. Tariff removal would result in a net global welfare gain, the size of which is about equal to the gain obtained by ethanol exporters.

Because both the blenders tax credit and the mandate increase the demand for ethanol, elimination of one of these would not have a large impact on domestic ethanol production. Removing both would reduce the expected domestic ethanol production by 10.3%, and removing all would decrease the production by 11.5%. Eliminating the import tariff while keeping the mandate and tax credit would increase average ethanol imports by about 220%.

The model presented here is currently being expanded to include the soybean complex and projections for more than one year. The resulting model will be used as a combination market outlook and policy analysis tool that can easily accommodate updated market information and crop conditions as they become available from NASS and WASDE. Price distributions that reflect the latest policies and market information will provide objective and transparent information about the impact of commodity and biofuels policies and crop developments on fuel, feed, and food prices.

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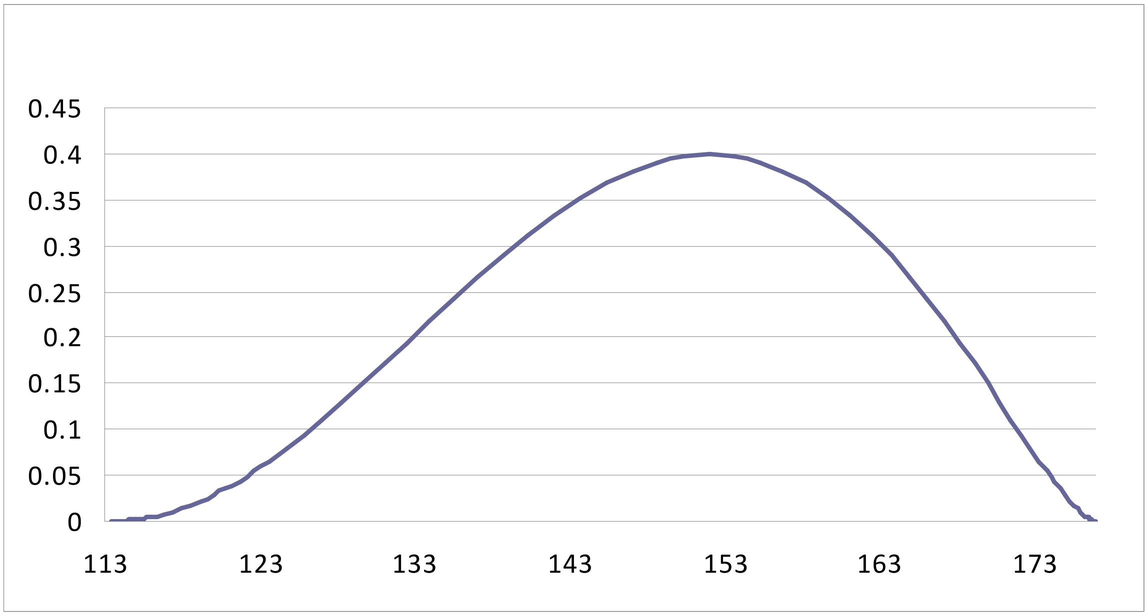

Figure 1: The distribution of corn yield (bushels per acre) for 2008

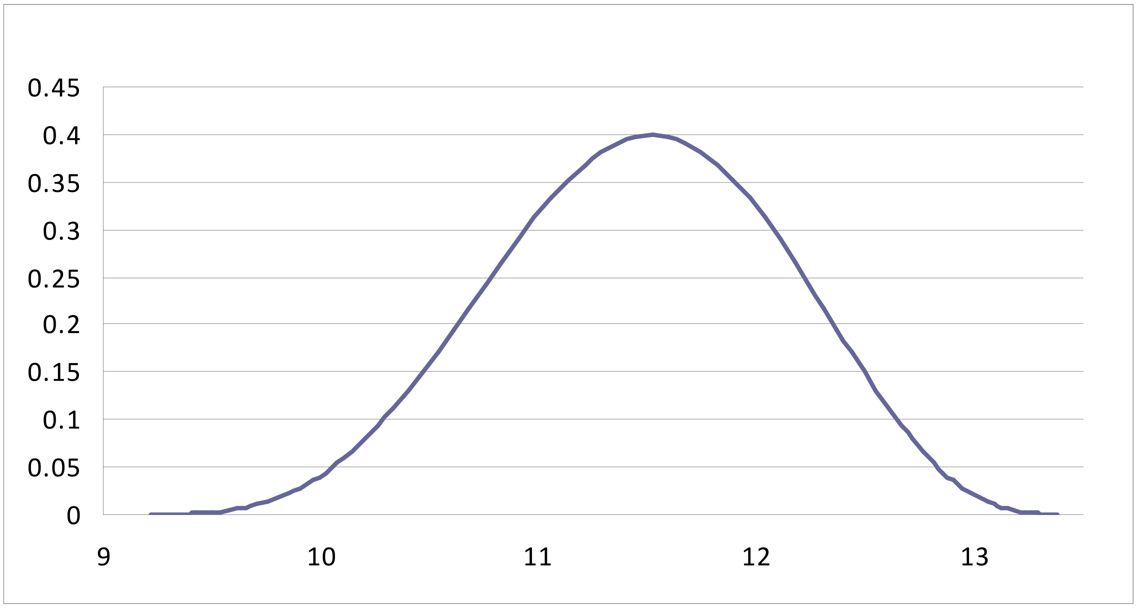

Figure 2: The distribution of ethanol production capacity (billion gallons) in the 2008/09 marketing year

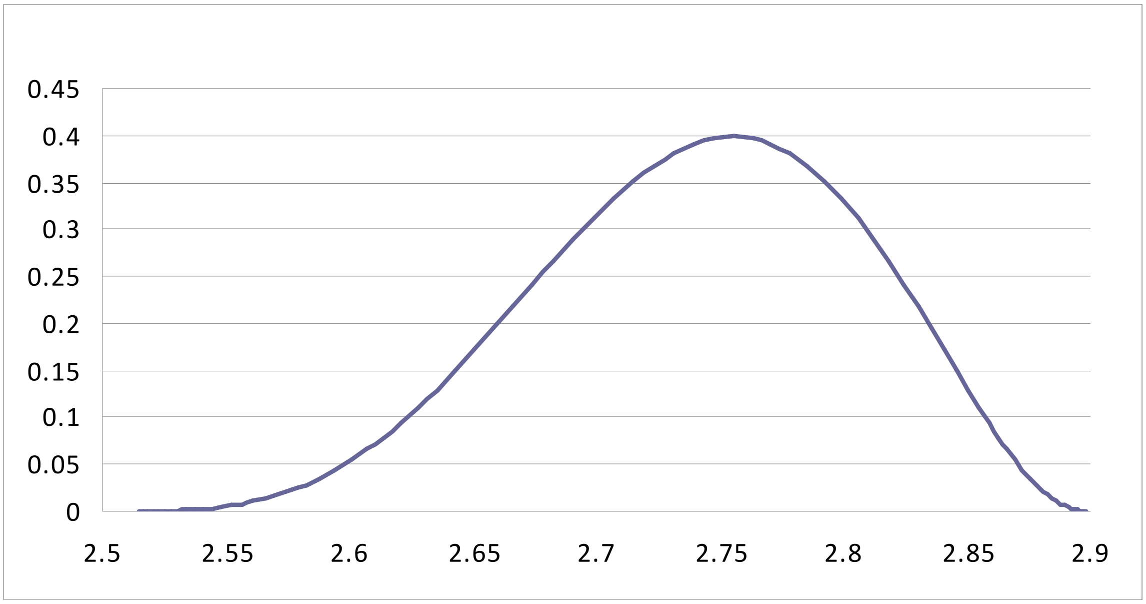

Figure 3: The distribution of ethanol production efficiency index (gallons per bushel)

Variable	Estimate	Std.	P-value
Planted acres	0.0872	0.0254	0.00
Time trend	-0.0926	0.0120	0.00
Percentage deviation in actual corn yields from trend yields	-4.7447	1.7476	0.01
Intercept	4.7014	1.8076	0.01
R Square	0.58		
Adjusted R Square	0.56		

Table 1. OLS regression results for non-harvested acres

Policy Scenario	Corn price	Ethanol price	Gas price	Corn feed demand	Corn food demand	Corn export demand	Corn ethanol demand	Corn storage demand	Ethanol domestic supply	Ethanol import supply	Gasoline domestic supply	% of ethanol plant running	Total ethanol demand	Total gas supply	Total fuel demand	Fuel price
	$/bu.	$/gal.	$/gal.	million bu.	million bu.	million bu.	million bu.	million bu.	million gal.	million gal.	million gal.		million gal.	million gal.	million gal.	$/gal.
Mandate, Tax Credit & Tariff	5.86	2.69	3.11	5,214	1,351	2,018	3,862	815	10,620	506	115,658	0.92	11,126	131,558	139,102	3.08
Tax Credit & Tariff	5.63	2.61	3.13	5,269	1,357	2,070	3,747	817	10,303	330	115,936	0.90	10,633	131,836	139,046	3.09
Mandate & Tariff	5.65	2.41	3.13	5,263	1,356	2,065	3,754	823	10,322	301	115,984	0.90	10,624	131,884	139,088	3.08
Mandate & Tax Credit	5.71	2.62	3.08	5,250	1,355	2,052	3,787	816	10,414	1,613	115,248	0.91	12,026	131,148	139,303	3.04
Mandate Only	5.41	2.32	3.13	5,323	1,362	2,122	3,625	828	9,969	951	115,875	0.87	10,921	131,775	139,181	3.06
Tax Credit Only	5.57	2.57	3.09	5,283	1,358	2,084	3,716	818	10,220	1,507	115,417	0.89	11,727	131,317	139,269	3.04
Tariff Only	5.10	2.22	3.17	5,397	1,370	2,192	3,465	836	9,529	31	116,573	0.83	9,560	132,473	138,956	3.10
No Programs	5.01	2.19	3.15	5,419	1,372	2,213	3,417	840	9,395	648	116,355	0.82	10,044	132,255	139,065	3.08

Table 2 (1). Impacts of federal ethanol policies over the period Sep. 1, 2008 to Aug. 31, 2009

Policy Scenario	Corn price	Ethanol price	Gas price	Corn feed demand	Corn food demand	Corn export demand	Corn ethanol demand	Corn storage demand	Ethanol domestic supply	Ethanol import supply	Gasoline domestic supply	% of ethanol plant running	Total ethanol demand	Total gas supply	Total fuel demand	Fuel price
	% change from current policy															
Tax Credit and Tariff	-3.9%	-2.9%	0.5%	1.1%	0.4%	2.6%	-3.0%	0.2%	-3.0%	-34.8%	0.2%	-3.0%	-4.4%	0.2%	0.0%	0.3%
Mandate and Tariff	-3.5%	-10.2%	0.8%	0.9%	0.4%	2.3%	-2.8%	0.9%	-2.8%	-40.5%	0.3%	-2.7%	-4.5%	0.2%	0.0%	0.1%
Mandate and Tax Credit	-2.5%	-2.5%	-1.0%	0.7%	0.3%	1.7%	-1.9%	0.2%	-1.9%	218.6%	-0.4%	-1.9%	8.1%	-0.3%	0.1%	-1.2%
Mandate Only	-7.7%	-13.7%	0.5%	2.1%	0.8%	5.2%	-6.1%	1.5%	-6.1%	88.0%	0.2%	-6.1%	-1.8%	0.2%	0.1%	-0.5%
Tax Credit Only	-4.9%	-4.2%	-0.7%	1.3%	0.5%	3.3%	-3.8%	0.4%	-3.8%	197.8%	-0.2%	-3.8%	5.4%	-0.2%	0.1%	-1.0%
Tariff Only	-13.0%	-17.3%	1.9%	3.5%	1.3%	8.6%	-10.3%	2.6%	-10.3%	-93.8%	0.8%	-10.2%	-14.1%	0.7%	-0.1%	0.9%
No Programs	-14.5%	-18.6%	1.4%	3.9%	1.5%	9.7%	-11.5%	3.0%	-11.5%	28.1%	0.6%	-11.5%	-9.7%	0.5%	0.0%	0.2%

Table 2 (2). Impacts of federal ethanol policies over the period Sep. 1, 2008 to Aug. 31, 2009

Policy Scenario	Change in PS of Corn Growers	Change in CS of Domestic Feeders	Change in CS of Food users	Change in CS of corn Importers	Change in CS of ethanol blenders	Change in PS of Ethanol Producers	Change in PS of Ethanol Exporters	Change in Government Revenue	Change in CS of Fuel users	Change in PS of gasoline producers	Net Welfare Gain
	Average change from current policy (Mandate, Tax Credit and Tariff) (in million $)										
Tax Credit and Tariff	-2373	1124	303	435	940	-54	-84	126	-1446	1877	846
Mandate and Tariff	-2431	1059	275	410	-909	-2417	-16	5106	-371	2752	3459
Mandate and Tax Credit	-1581	730	197	276	453	-229	561	-1391	5083	-3531	568
Mandate Only	-5162	2314	608	891	-44	-2577	213	4925	1990	1724	4882
Tax Credit Only	-2994	1422	382	551	1006	-251	454	-1187	4218	-2415	1187
Tariff Only	-8423	3888	1020	1523	1460	-2577	-112	4944	-3747	6896	4984
No Programs	-9392	4366	1144	1722	1621	-2647	3	4925	-975	5051	5817

Table 3. Welfare impacts of federal ethanol policies over the period Sep. 1, 2008 to Aug. 31, 2009