International Variability in Biofuel Trade: An Assessment of U.S. Policies

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Abstract

Although the United States has typically been in a position to import ethanol, corn-based ethanol exports are surging as the domestic market becomes saturated and world prices rise due to high prices for sugar, the competing global feedstock. The U.S. is now the world's leading ethanol producer but domestic demand is constrained because of technical limitations in the current vehicle fleet. Higher ethanol blends have been approved for use (15% rather than 10%) but a limited number of vehicles that can use such higher blends. Infrastructure constraints also affect the potential supply of higher ethanol blends. As a result of these factors, U.S. biofuel policies can have significant implications for the world ethanol market. Usage mandates under the Renewable Fuel Standard, blender tax credits, and the blend wall can interact to generate excess supplies of ethanol that are likely to be diverted to the world market. This paper examines how fluctuations in corn yield and gasoline prices affect the excess supply of U.S. corn-based ethanol in the presence of alternative assumptions about the maximum amount of ethanol that can be consumed domestically. Using stochastic simulations we also explore the impact of current policies on the mean and variance of export supply. The results highlight the complex interaction between technological constraints, economic incentives, and government policies in the U.S. biofuels sector, and point to the potentially destabilizing effect of such policies in international markets.

Keywords: Ethanol Exports, Biofuel Policies, Variability

1. Introduction

Since the enactment of the Energy Policy Act of 2005, the ethanol industry in the United States, based primarily on maize (corn) as a feedstock, has expanded dramatically with a roughly three-fold increase in ethanol production. Proponents of ethanol advocate its use on several grounds, such as reducing greenhouse gas emissions, improving energy security, increasing farm incomes, and job creation. The major U.S. policy instruments to promote domestic ethanol use are tax credits for blending the product with gasoline, an import tariff on fuel ethanol, and the Renewable Fuel Standard (RFS) which requires minimum usage levels for renewable fuels. In addition to these policy instruments, there has been an increase in demand for ethanol due to higher gasoline prices and the ban on the use of MTBE (Methyl Tertiary-Butyl Ether) as an oxygenate to reduce air pollution. Ethanol is a substitute for MTBE in this respect. Increases in corn yields and improved efficiency in corn-to-ethanol conversion technology have also contributed to the development of the industry.

Prior to the rapid growth in the domestic industry the United States was an importer of ethanol, mainly from Caribbean countries and Brazil, though imported fuel ethanol accounted for only small part of total U.S. ethanol consumption due to a tariff rate quota for Caribbean supplies and tariffs applied to other supplies. However, the nation is quickly evolving into a net exporter of fuel ethanol (RFA, 2010a). A major factor in this development is the saturation of the domestic market due to a so-called "blend wall" – a limit on the maximum amount of ethanol that can be consumed domestically due to technical limitations in the current vehicle fleet (Wisner, 2010). High world sugar prices have caused tighter sugar-based export supplies of ethanol from Brazil. The U.S. industry has also benefited from cost reductions in ethanol production. Since the U.S. is now the world's leading ethanol producer and faces constraints on domestic usage due to the blend wall, U.S. biofuel policies are likely to have implications for the world ethanol market.

This paper examines how fluctuations in corn yields and gasoline prices influence the excess supply of U.S. corn-based ethanol, taking into account limitations on domestic use. We explore the impact of current policies on the mean and variance of export supply. To the best of our knowledge, U.S. fuel ethanol export potential has not been assessed analytically in the literature. Building on the work of McPhail and Babcock (2008), we develop a stochastic partial equilibrium model in which corn yield per harvested acre and the price of gasoline are variable and simulate excess supply adjustments in response to external shocks and changes in policies. The simulation model is calibrated to 2009/10 data for the corn and energy market.

The remainder of the paper is organized as follows. The following section summarizes current major U.S. biofuel policies. The current market situation is discussed in section 3. We present our partial equilibrium model and assumptions in section 4. In section 5, the results of simulations are presented and discussed. The final section summarizes our conclusions and their implications.

2. Current U.S. Biofuel Policies

The principal current U.S. policies for ethanol include a tax credit for blenders, tariffs on imports, and mandates for biofuel use. Fuel blenders can claim a tax credit for blending biofuels with petroleum-based fuels. Presently, the Federal ethanol tax credit (Volumetric Ethanol Excise Tax Credit) is 45 cents per gallon. Import tariffs consist of a 2.5% *ad valorem* tariff and a secondary specific tariff of 54 cents per gallon. Tariffs exist to offset the credit that U.S. blenders would otherwise receive for using imported ethanol and hence to promote the use of domestic supplies. On the 17th of December 2010, President Obama signed legislation extending the ethanol tax credit and the secondary tariff on imported ethanol for one-year (U.S. Congress 2010, the bill HR 4940 was introduced on March 25th 2010).

The Renewable Fuel Standard (RFS), which was first established by the Energy Policy Act of 2005 and amended by the Energy Independence and Security Act of 2007 (EISA, U.S. Congress, 2007), requires the use of the minimum volume of renewables in transportation fuel sold or introduced into commerce in the United States. Blenders must submit Renewable Identification Numbers (RINs), which are assigned to each batch of renewable fuel by a producer or importer, to the Environmental Protection Agency (EPA) as evidence that they comply with the RFS. The overall mandate, for the applicable volume of renewable fuel, requires blenders to incorporate 13.95 billion gallons of renewables with petroleum-based fuels in 2011. The mandated volume rises steadily to 36 billion gallons by 2022. There are also secondary mandates. The advanced biofuel mandate is the largest of these and embraces two other mandates: the cellulosic biofuel mandate and biomass-based diesel mandate. The advanced biofuel mandate has to be achieved through renewable fuel other than corn-based ethanol. It is likely that imported sugarcane-based ethanol (most likely sourced from Brazil), cellulosic ethanol, and biomass-based diesel will be used to meet that mandate. Corn-based ethanol can be used to fill the difference between the overall mandate and the advanced biofuel mandate.

3. Current Market Situation

According to recent news reports, the U.S. ethanol industry is approaching a so-called blend wall, referring to the maximum amount of ethanol that can be blended with gasoline (Wisner, 2010). On the 21st of January 2011, the U.S. Environmental Protection Agency (EPA) approved the use of up to 15% of ethanol (E15) in gasoline blends for model year 2001 and newer cars and light trucks (EPA, 2011). Ethanol blends of up to 10% (E10) had been approved prior to this because all vehicles, regardless of their age, can use such blends. According to the Renewable Fuels Association (RFA), E15 is suitable for roughly 62 percent of the gasoline powered vehicles in the United States. The engines of older vehicles can be damaged by higher ethanol blends.

If all eligible vehicles were to use E15, the domestic market potential for ethanol would be approximately 17.5 billion gallons under recent market conditions. Under the E10 limitation it was roughly 12.5-13.5 billion gallons (RFA, 2010a). However, the EPA decision may not have much immediate impact on domestic market potential for ethanol. To sell E15 alongside E10, the owners of service stations would typically have to add an additional underground tank. Otherwise they would need to switch their tanks over to E15. In either event, it would be expensive for fuel retailers to sell the product. Also, given the potential for damage to a significant proportion of the existing vehicle fleet, retailers could face labeling and misfueling issues. Since the EPA cannot force anyone to sell E15, many retailers may choose not to adopt the product until the fleet becomes dominated by suitable vehicles. Consequently, it is to be expected that the use of E15 will spread slowly. In addition, U.S. demand for E85 (85% ethanol) or higher ethanol blends (e.g., E20) is expected to remain small for the foreseeable future because of the limited number of vehicles that can use higher blend ratios (flex fuel vehicles) and the lack of infrastructure (pumps at service stations) to deliver these blends (Taheripour and Tyner, 2008). Thus, although the domestic demand for ethanol is expected to continue to increase, the growth is likely to be much lower than the U.S. has experienced in recent years.

As the domestic market has become saturated, U.S. fuel ethanol exports have increased sharply. According to an RFA press releases (RFA, 2010c), as of the 10th of December 2010, more than 325 million gallons of fuel ethanol were expected to be exported in 2010. Tighter supplies of sugarcane-based ethanol from Brazil due to high world sugar prices have contributed to a rapid increase in U.S. fuel ethanol exports. Even if world ethanol prices fall, exports could remain strong due to the limited domestic market and U.S. biofuel policies. Under the current mechanism, there is no restriction on the final destination of ethanol blends after blenders collect the tax credit. This means that potentially subsidized ethanol-gasoline blends could be exported to countries where these can be used. The tax credit could therefore stimulate ethanol exports, even if world ethanol prices fall. It is highly likely that if the mandated amount of biofuels under the RFS exceeds the amount that can be consumed domestically, the excess supply of ethanol will be diverted to international markets, unless the RFS mandate is waived by the EPA.

Given this complex market situation, there is the potential that excess supply will be highly variable. The supply of U.S. ethanol is influenced by the price of feedstock (corn), the price of petroleum, as well as the height of the blend wall and its relationship to the RFS mandates. The supply of corn and its price can fluctuate sharply from year to year as a result of variations in supply, as has been illustrated by price movements in recent years. In addition, petroleum prices can also vary markedly through time. Consequently, we need a model that captures the interaction between the key technical and policy factors and responses in the ethanol market in order to examine the implications for the potential variability of ethanol exports.

4. Model Structure

Building upon the work of McPhail and Babcock (2008), a stochastic partial equilibrium model is developed to evaluate the impact of policies and external shocks on the excess supply of corn-based ethanol. Data for the 2009/10 marketing year are used for model calibration. Excess supply is measured by the difference between the quantity of ethanol supplied domestically at the prevailing ethanol price in the absence of the blend wall and the maximum quantity that can be consumed domestically in the presence of the blend wall. If this difference is negative, excess supply is zero unless the mandated amount under the RFS exceeds feasible domestic consumption and blenders comply with the mandate. We consider two sources of shocks in the short-run: corn yield and gasoline prices. Variations in corn yields and gasoline prices within a given year are assumed to be independent[1].

Corn Market

Corn production is determined by multiplying harvested acres by corn yield per harvested acre

$$Q_c^S = h_c \times \tilde{y}_c , \quad (1)$$

where Q_c^S is corn production, h_c is harvested acres, and $\tilde{y}_c$ represents realized yield per harvested acre. According to the U.S. Department of Agriculture (USDA) World Agricultural Supply and Demand Estimates (WASDE; USDA, 2011), harvested acres, corn yield and total production were 79.5 million acres, 164.7 bushels, and 13,092 million bushels, respectively, in the 2009/10 marketing year. Following McPhail and Babcock (2008), corn yield is assumed to have a beta distribution. Total supply of corn is obtained by adding the beginning stock of corn Q_c^{BS} (1,673 million bushels) and the modest volume of imports Q_c^I (8 million bushels) to total production.

Total corn demand can be decomposed into five components: feed, food, storage, exports, and the demand for ethanol production. All demand curves, which depend on the average price received by farmers in the 2009/10 marketing year, are assumed to be linear except for demand by the ethanol industry.

$$Q_c^{D,i} = g^i(p_c) = a_i - b_i \times p_c , \; i = \text{food, feed, storage, exports,} \quad (2)$$

where $Q_c^{D,i}$ denotes the demand of corn from food, feed, storage, or exports and p_c represents the price of corn. Parameters for these demand curves are obtained using assumed demand elasticities and calibrating to USDA projections in the WASDE report for January 2011. The average farm price of corn p_c in the 2009/10 marketing year was \$3.55 per bushel. Feed and residual use, food and seed use, ending stocks, and exports were 5,140 million bushels, 1,371 million bushels, 1,708 million bushels, and 1,987 million bushels, respectively. Following McPhail and Babcock (2008), the demand elasticities for feed, food, storage, and exports are assumed to be: -0.25, -0.096, -0.65, and -0.6, respectively. The demand curves in the 2009/10 marketing year are therefore

[1] Historically, the correlation between energy and corn prices has been low (Muhammad and Kebede, 2009).

$$Q_c^{D,feed} = 6425 - 362 \times p_c , \tag{3}$$

$$Q_c^{D,food} = 1503 - 37 \times p_c , \tag{4}$$

$$Q_c^{D,storage} = 2818 - 313 \times p_c , \tag{5}$$

$$Q_c^{D,export} = 3179 - 336 \times p_c . \tag{6}$$

The demand for corn for ethanol $Q_c^{D,ethanol}$ is determined by ethanol production capacity, C (billion gallons), the percentage of capacity that is in operation η, and the number of bushels of corn needed to produce a gallon of ethanol δ

$$Q_c^{D,ethanol} = \eta \cdot C \cdot \delta . \tag{7}$$

According to FAPRI (2007), the average number of gallons of ethanol produced from a bushel of corn is 2.75 gallons, therefore $\delta = 1/2.75$.

In the short-run, it is assumed that the capacity utilization ratio η depends on the current period operating margin per bushel, which is a function of the corn price and the ethanol price. Therefore, ethanol production capacity and production efficiency are fixed. According to an RFA press releases on 28th of May 2010 (RFA, 2010b), dry mill facilities represented nearly 90 percent of America's total ethanol production in 2010. Thus, we focus on dry mill ethanol plants. Following McPhail and Babcock (2008), the operating margin per bushel of corn processed, π, for a dry mill ethanol plant can be expressed as

$$\pi = 2.75 \times (p_e - 0.54) - 0.86055 p_c + 0.44625 , \tag{8}$$

where p_e is the price of ethanol. The demand for corn for ethanol production can be rewritten as

$$Q_c^{D,ethanol} = \eta(\pi(p_c, p_e)) \cdot C \cdot \delta . \tag{9}$$

Because the capacity utilization rate lies between zero and one, a logistic form is used to simulate changes in this. Hence,

$$\eta(\pi) = \frac{1}{1 + e^{-\alpha + \beta\pi}} , \tag{10}$$

where $\alpha = -0.99259$ and $\beta = 1.96852$.

Energy Market

From equation (9), given the price of corn and the price of ethanol, the supply of ethanol Q_e^S can be written as

$$Q_e^S = \eta(\pi(p_c, p_e)) \cdot C . \tag{11}$$

The demand for ethanol is assumed to be perfectly elastic at its energy value in the absence of the mandate and blend wall. According to de Gorter and Just (2010), the price of ethanol with a tax credit s and a fuel excise tax t is

$$p_e = \gamma \cdot p_g + s - (1 - \gamma) \cdot t , \tag{12}$$

where p_g is the price of gasoline and γ is the fuel efficiency index which is assumed to be 0.68. Given the gasoline price and the corn price, ethanol supply in the absence of the mandate and blend wall is determined by equation (11). The average gasoline price in the 2009/10 marketing year was \$2.70 per gallon, calculated using monthly data obtained from the Agricultural Marketing Resource Center (Ethanol Basis Data). Given the tax credit \$0.45 per gallon and fuel tax \$0.184 per gallon, estimated (expected) ethanol price from equation (12) is \$2.23 per gallon. The gasoline price is assumed to be normally distributed.

Blend wall

The maximum volume of corn-based ethanol that can be consumed domestically depends on total fuel use and the RFS. The demand for mixed fuel is assumed to be linear

$$Q_{mf}^{D} = g(p_{mf}) = a_{mf} - b_{mf} \times p_{mf}\,, \qquad (13)$$

where Q_{mf}^{D} denotes the demand of mixed fuel and p_{mf} is the price of mixed fuel. The price of mixed fuel is given by

$$p_{mf} = \theta \cdot p_e + (1-\theta) \cdot p_g\,, \qquad (14)$$

where θ represents the share of ethanol in the total fuel mix. Since gasoline and ethanol are different products, if θ changes, the parameters of the demand function also change. The feasible domestic ethanol consumption Q_e^{BW} in the presence of the blend wall is calculated by

$$Q_e^{BW} = \theta \cdot Q_{mf}^{D}\,. \qquad (15)$$

If the advanced biofuel mandate is enforced and met by blenders, the maximum amount of corn-based ethanol that can be consumed domestically is smaller than Q_e^{BW} because it is likely that imported sugarcane-based ethanol and cellulosic ethanol would be used to meet the part of the advanced biofuel mandate. Hence, in order to obtain the 'effective' maximum amount of corn-based ethanol that can be consumed domestically, we subtract the mandated amount of advanced biofuels less mandated biodiesel use from Q_e^{BW}. We use the term 'effective blend wall' for that amount in the reminder of the paper. The effective blend wall is given by

$$Q_e^{EBW} = Q_e^{BW} - (Q_r^{RFSA} - Q_{bd}^{RFSA})\,, \qquad (16)$$

where Q_e^{EBW} is the effective blend wall quantity, Q_r^{RFSA} is the mandatory advanced biofuel use, and Q_{bd}^{RFSA} is the mandated biodiesel quantity which is a part of the advanced biofuel mandate.

According to the Energy Information Administration (EIA), U.S. total fuel consumption in 2009 was 137.916 billion gallons (gasoline plus ethanol). We use this number in our simulations. In 2010, the domestic market potential for ethanol was predicted to be approximately 12.5-13.5 billion gallons (RFA, 2010a). Therefore, we set $\theta = 0.09$ (9%) as the most pessimistic case for domestic market use of ethanol. For more optimistic cases, the maximum ethanol share is assumed to be $\theta = 0.10$ (10%) or $\theta = 0.11$ (11%). The demand curves for mixed fuel with $\theta = 0.09$, $\theta = 0.10$, and $\theta = 0.11$ are

$$Q_{mf}^{D} = 165.5 - 10.38 \times p_{mf} \text{ with } \theta = 0.09\,, \qquad (17)$$

$$Q_{mf}^{D} = 165.5 - 10.40 \times p_{mf} \text{ with } \theta = 0.10\,, \qquad (18)$$

$$Q_{mf}^{D} = 165.5 - 10.42 \times p_{mf} \text{ with } \theta = 0.11\,. \qquad (19)$$

Excess supply of corn-based ethanol

Given the supply of ethanol in the absence of the blend wall and the effective blend wall volume, the excess supply of corn-based ethanol at p_e is

$$Q_e^{ES} = Q_e^{S} - Q_e^{EBW}\,. \qquad (20)$$

If $Q_e^{ES} < 0$, then $Q_e^{ES} = 0$. Considering current technologies and tariffs on imported ethanol, it is likely that corn-based ethanol would be used to achieve the total RFS less the advanced biofuel mandate (Thompson *et al*. 2009). If this mandated amount exceeds the effective blend wall and blenders comply with the mandate, extra corn-based ethanol would be diverted to international markets whatever the level of world ethanol prices. The mandated amount less the effective blend wall volume could exceed excess supply in the absence of the mandate. Consequently, excess supply is

$$Q_e^{ES} = \begin{cases} Q_r^{RFS} - Q_r^{RFSA} - Q_e^{EBW} & if \quad Q_e^{ES} < Q_r^{RFS} - Q_r^{RFSA} - Q_e^{EBW} \\ Q_e^{ES} & if \quad Q_e^{ES} \geq Q_r^{RFS} - Q_r^{RFSA} - Q_e^{EBW} \end{cases}, \tag{21}$$

where Q_e^{RFS} is the mandated total renewable fuel volume. The supply of ethanol in the presence of the mandate is

$$Q_e^{S} = \begin{cases} Q_r^{RFS} - Q_r^{RFSA} & if \quad Q_e^{S} < Q_r^{RFS} - Q_r^{RFSA} \\ Q_e^{S} & if \quad Q_e^{S} \geq Q_r^{RFS} - Q_r^{RFSA} \end{cases}. \tag{22}$$

Finally, the equilibrium corn price and ethanol supply without the blend wall and the mandate (if the mandate is binding, ethanol supply equals the mandated volume) can be obtained by solving the following market clearing condition

$$Q_c^S + Q_c^{BS} + Q_c^I = Q_c^{D,\,feed} + Q_c^{D,\,food} + Q_c^{D,storage} + Q_c^{D,ex\,port} + Q_c^{D,ethanol}. \tag{23}$$

5. Simulation Results

This section provides the results of simulations. Although the model developed in the previous section is calibrated to the 2009/10 corn and energy market data, we establish a baseline that incorporates potential expansion of ethanol production capacity. According to the Nebraska Government, as of December 2010, the nation's ethanol production capacity was 13,771 million gallons (about 13.8 billion gallons) with 840 million gallons of capacity under construction (Nebraska Energy Office, 2011). We assume that 50% of the capacity under construction would be available, resulting in a total of 14.2 billion gallons of ethanol production capacity. Since the RFS requirements are increasing annually, we set the mandates at their 2011 level: the total RFS is 13.95 billion gallons, the advanced biofuel mandate is 1.35 billion gallons, and the biomass-based diesel mandate is 0.8 billion gallons. The price of corn in the baseline is $3.78 per bushel. The excess supply (ethanol supply without the blend wall less the effective blend wall amount) is 1.37 billion gallons if the maximum ethanol share is 9%, and zero for other two cases (10% and 11%).

Table 1 shows how changes in corn yield and/or gasoline price affect the excess supply of corn-based ethanol and the price of corn. To compare the baseline with various scenarios, we increase or decrease corn yield and/or gasoline price by 10%. A 10% reduction in corn yield is consistent with the USDA WASDE projection for the 2010/11 marketing year. Given a gasoline price of $2.70 per gallon, a lower corn yield decreases the excess supply of ethanol to 0.239 billion gallons with $\theta = 0.09$ and increases the average corn price to $4.29 per bushels. Since corn-based ethanol supply is less than the mandate, if blenders comply, 0.738 billion gallons of excess supply and a $4.47 per bushel price of corn result. Conversely, if corn yield is decreased by 10%, excess supply is increased significantly to 2.144 billion gallons with $\theta = 0.09$ or 0.765 billion gallons with $\theta = 0.10$. The price of corn is reduced to $2.80 per bushel. Holding corn yield at the baseline level, if the gasoline price falls by 10%, both excess supply and the corn price are decreased (0.452 billion gallons and $3.54 per bushel). If the mandate is met, a slightly higher excess supply and corn price will result. If the gasoline price is increased by 10%, both excess supply and the corn price will be increased (2.075 billion gallons and $3.95 per bushel). Excess supply is highest if both corn yield and the gasoline price increase. This is because a high corn yield reduces ethanol production costs and a high gasoline price increases the demand for ethanol. The price of corn is highest if lower yield and a higher gasoline price occur because the supply of corn will be tighter, whereas the demand for corn by the ethanol industry will be increased. Finally, if $\theta = 0.11$, excess supply is always zero, but as discussed above, such a high usage rate is unlikely because E15 is unlikely to be adopted rapidly in the domestic market.

Table 2 summarizes the impact of biofuel policies on the mean and variability of excess supply and the corn price. Using the econometric software package TSP 5.0 (Hall and Cummins, 2005) we generated 500 random values for corn yield and gasoline price, with the mean at the baseline level and the coefficient of variation of 0.1 for both. We consider four scenarios: only corn yield is stochastic; only gasoline price is stochastic; both are stochastic; and both are stochastic but the tax credit cannot be collected for exports. If the maximum ethanol share in total fuel use is 9%, the mandate increases the mean of excess supply but reduces its variability. This is because the mandated amount of ethanol sometimes exceeds the effective blend wall volume or ethanol supply without the blend wall. For $\theta = 0.10$, the mandate has no impact because the effective blend wall volume is always higher than the mandated volume. Also, enforcement of the mandate results in higher variability in the corn price when corn yield fluctuates because the demand for corn from ethanol becomes more stable. If the tax credit is not applicable to exports, excess supply and the corn price will be reduced significantly. The impact of the RFS is the same as before.

6. Conclusions

This paper analyzes the impacts of changes in corn yield and gasoline prices on the excess supply of U.S. corn-based ethanol at the prevailing ethanol price under various scenarios. We also explore how current U.S. biofuel policies influence the mean and variance of export supply. To do so, we develop a stochastic partial equilibrium model in which corn yield and the price of gasoline are stochastic. We use 2009/10 corn and energy market data for model calibration.

Our results show that if the domestic market potential for corn-based ethanol in the United States is limited due to a blend wall, both corn yield and gasoline price have a significant impact on the excess supply of ethanol directed to world markets. If blenders comply with the RFS, this could exceed the maximum amount of corn-based ethanol that can be absorbed domestically and increase the expected amount of excess supply, but also reduce its variability. Under the current policy mechanism, after blenders collect the tax credit by blending ethanol with gasoline, mixed fuels can be delivered anywhere and the tax credit could stimulate corn-based ethanol exports. The results of our simulations also show that the excess supply is greatly reduced if the tax credit is not applicable to exports. However, variability in excess supply is increased.

Recently, the marketing of up to 15% ethanol blends (E15) was approved. This can be used by roughly 60% of all vehicles on the road today in the United States. Nevertheless, the domestic market potential for ethanol is likely to expand slowly. If the blend wall continues to constrain domestic consumption of blended fuel, current U.S. biofuel policies could have significant impact on the world ethanol market in the presence of fluctuations in corn yields and petroleum prices.

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Table 1: Simulation results for various scenarios

Scenarios	Corn Yield (bu/acre)	Gasoline Price ($/gallon)	Ethanol Supply w/o Blend Wall (billion gallons)	Excess Supply EBW 9% (billion gallons)	Excess Supply EBW 10% (billion gallons)	Excess Supply EBW 11% (billion gallons)	Corn Price ($/bu)
Baseline	164.7	2.70	13.23	1.370	0	0	3.78
10% Reduction in Corn Yield	152.8	2.70	12.10 (12.60)	0.239 (0.738)	0	0	4.29 (4.47)
10% Increase in Corn Yield	181.2	2.70	14.01	2.144	0.765	0	2.80
10% Reduction in Gasoline Price	164.7	2.43	12.55 (12.60)	0.452 (0.507)	0.000	0	3.54 (3.56)
10% Increase in Gasoline Price	164.7	2.97	13.71	2.075	0.719	0	3.95
10% Reduction in Corn Yield and Gasoline Price	152.8	2.43	11.17 (12.6)	0 (0.507)	0	0	3.97 (4.47)
10% Increase in Corn Yield and Gasoline Price	181.2	2.97	14.13	2.413	1.057	0	2.81
10% Reduction in Corn Yield and 10% Increase in Gasoline Price	152.8	2.97	12.89	1.253	0	0	4.57
10% Increase in Corn Yield and 10% Reduction in Gasoline Price	181.2	2.43	13.76	1.663	0.260	0	2.71

"EBW" means the effective blend wall with ethanol share 9%, 10%, and 11%
Numbers in parenthesis show the results if blenders comply with the RFS (if numbers are the same, there is no parenthesis)

Table 2: Mean and coefficient of variation (CV) of excess supply and corn price

Stochastic Variables (Policy)	RFS	Excess Supply (billion gallons)						Corn Price ($/bu)	
		EBW 9%		EBW 10%		EBW 11%			
		Mean	CV	Mean	CV	Mean	CV	Mean	CV
Corn Yield	Not Comply	1.249	0.69	0.317	1.11	0	N/A	3.63	0.22
	Comply	1.449	0.42	0.317	1.11	0	N/A	3.8	0.28
Gasoline Price	Not Comply	1.341	0.30	0.153	1.45	0	N/A	3.77	0.02
	Comply	1.341	0.30	0.153	1.45	0	N/A	3.77	0.02
Corn Yield and Gasoline Price	Not Comply	1.253	0.73	0.348	1.26	0	N/A	3.62	0.24
	Comply	1.449	0.42	0.348	1.26	0	N/A	3.8	0.29
Corn Yield and Gasoline Price (Tax Credit Not Applicable)	Not Comply	0.481	1.50	0.081	3.02	0	N/A	3	0.23
	Comply	0.923	0.54	0.081	3.02	0	N/A	3.62	0.33

10% CV for both corn yield and gasoline price, "EBW" means the effective blend wall with ethanol share 9%, 10%, or 11%