RFS Compliance Costs and Incentives to Invest in Ethanol Infrastructure

by Bruce A. Babcock

Executive Summary

At the request of the oil industry and livestock groups, Congress and the Environmental Protection Agency (EPA) are considering whether to reduce biofuel blending mandates. Livestock groups want lower corn prices and the oil industry claims that it simply cannot blend more biofuels than current levels. The oil industry argues that its only compliance option is to reduce domestic gasoline and diesel sales if mandates are not reduced; however, an alternative compliance path is to increase the demand for ethanol by investing in E85 fueling capabilities. Ethanol demand would increase by between 800 million and one billion gallons per year for each 2,500 stations with E85 fueling capabilities given the existing fleet of flex vehicles. The cost of investing in E85 at existing stations depends on whether a new tank needs to be installed or whether an existing tank can be converted. If new tanks need to be installed then the cost of 2,500 stations would be at least $325 million. If no new tanks need to be installed then the cost would be approximately $87.5 million. With the price of the tradable ethanol credits trading between $0.60 and $0.70 per gallon, and with at least 14 billion credits needed under current mandates, it seems that the reduction in compliance costs could be greater than the costs of investing in E85 infrastructure, which would create an incentive for investment. Simulation results show that this is indeed the case if EPA sets mandates that are attainable with investment. If EPA sets 2014 mandates that can be met with 13.9 billion gallons, then investment in 2,500 E85 stations would reduce oil company compliance costs from $2.84 billion to $1.09 billion. If EPA sets 2015 requirements that can be met with 14.7 billion gallons, then 2015 compliance costs would be reduced by more than $2.4 billion dollars from investment in an additional 2,500 E85 stations. Taxpayers, gas station owners, or oil companies could pay for the investment. Congress could divert farm subsidies to pay for E85 investment with a justification that an important beneficiary of ethanol is land-owning farmers. Gas station owners will have an incentive to make the investment if the wholesale price of E85 drops enough to generate fuel cost savings to drivers as well as higher wholesale-retail margins to station owners. Oil companies might find it more efficient to make the investment themselves if the required price of ethanol credits rises too high for too long.

RFS Compliance Costs and Incentives to Invest in Ethanol Infrastructure

By Bruce A. Babcock
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One of the issues that Congress may try to address this fall is whether to revise the biofuel blending mandates in the Renewable Fuels Standard (RFS). As with so many issues facing Congress this year, many of the arguments used to sway public opinion about the RFS are self-serving. In this article, I make three possibly useful contributions to the debate. First, I use an economic model to estimate the cost to oil companies to comply with RFS mandates in 2014 and 2015. Second, I show how these compliance costs can be reduced through investment that increases the number of gasoline stations that can sell E85. I show that the reduction in compliance costs can be greater than the cost of investment, thereby creating an investment incentive. Third, I discuss why keeping RFS mandates will not significantly increase the price of gasoline.

The reason why Congress may revisit this issue of RFS mandates is that oil companies and livestock groups have combined efforts to lobby for lower blending mandates. The main argument put forth by oil companies is that blending targets are greater than the amounts of biofuels that can be consumed domestically. The maximum amount of ethanol that can be consumed as E10 (10 percent ethanol) is approximately 13 billion gallons because US motorists consume about 132 billion gallons of gasoline per year. The Environmental Protection Agency (EPA) has approved the sale of E15 for 2001 and later model year cars, but resistance to E15 by car manufacturers and many retailers, combined with an extensive lobbying campaign against E15, has limited sales and interest in the fuel. Ethanol consumption in E85 is limited by the number of stations that sell the fuel and by the number of flex-fuel cars that can use the fuel. In addition, E85 has been priced too high to generate fuel cost savings to consumers, thus limiting its appeal.

Livestock groups oppose ethanol mandates because they want to lower the cost of feed. Corn is the major ingredient in livestock feed rations and is by far the major feedstock used to produce ethanol in the United States. The rapid increase in ethanol production from 2006 to 2010 combined with a sequence of years with relatively poor growing conditions has led to sharp increases in corn prices, which have increased the cost of producing meat, eggs, and dairy products.

Oil companies argue that because of limits on ethanol consumption they simply cannot meet the scheduled blending targets in 2014 and 2015 and that their only alternative will be to sharply reduce sales of gasoline and diesel in order to comply.[1] They argue that such a reduction will dramatically increase the price of gasoline and diesel and reduce gross domestic product by a substantial amount.

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[1] The arguments are based at least in part on a study commissioned by the American Petroleum Institute and conducted by NERA Economic Consulting (2012). The petition for a partial waiver of RFS mandates submitted by the American Petroleum Institute and the American Fuel & Petrochemical Manufacturers explicitly states that domestic supplies of gasoline and diesel will be limited without a waiver.

Some may sympathize with oil companies. The price of renewable ethanol credits (called RINs or Renewable Identification Numbers) that are needed to comply with blending regulations are trading at about $.70 per gallon, and oil companies will need about 14 billion ethanol RINs to show compliance in 2013. This would seem to represent a cost of almost $10 billion per year if one simply multiplies the price of RINs by the quantity. However, the cost of complying with RFS mandates is not so simply calculated. What is a cost to a buyer represents a benefit to a seller, so part of the cost of compliance with mandates represents a transfer from ethanol sellers to ethanol buyers. In addition, part of the cost of RINs accrues back as a benefit to oil companies in the form of less expensive fuel. Standard welfare economics provides the tools to show that the actual cost to oil companies from compliance with biofuel mandates is much lower than $10 billion per year.

There is validity to the oil industry claim that it will be physically impossible to blend all the biofuel that is currently scheduled to be blended. Mandates are scheduled to increase significantly beyond the 13 billion gallons that can be consumed as E10. Two recent studies by Babcock and Pouliot (2013a, 2013b) show that not much more than one billion gallons of E85 consumption is economically viable with the current infrastructure. Their studies took into account the location of current gas stations that sell E85 as well as the location of flex vehicles to account for the cost of driving to a station. In addition, their one billion gallon result assumes that not more than 45,000 gallons of E85 can be sold by an individual station. Their result means that not more than about 14 billion gallons of ethanol can reasonably be expected to be consumed without more investment in E85 stations. However, Babcock and Pouliot (2013b) also show that E85 consumption could be increased significantly by creating more E85 stations in locations where there are a significant number of flex vehicles. Their demand estimates imply that between 800 and 900 million extra gallons of ethanol could be consumed in E85 for every 2,500 additional stations that sell the fuel. According to EPA (2010) the cost of enabling 2,500 gas stations to sell E85 ranges from $85 million to more than $300 million.

The cost to oil companies from complying with EPA mandates that force ethanol consumption beyond E10 is based on standard tools of welfare economics using estimated ethanol supply and demand curves. A comparison of the compliance costs across different mandate and demand scenarios can be used to determine the incentive to lower compliance costs by investing in E85 infrastructure that increases demand for ethanol. Results indicate that the benefit-to-cost ratio to oil companies from investing in the lowest cost E85 infrastructure (tank conversion and new pumps) can be greater than 10 to 1. Investment in higher-cost infrastructure (installation of a new tank and pump) can be greater than 3 to 1. The scope of this study is limited to the role that E85 can play in meeting expanded biofuel mandates. Biodiesel, E15, and drop-in biofuel options are not considered.

Simple Welfare Effects of an Ethanol Mandate
Abstracting from the actual fuel production, blending, and distribution systems that are in place, assume that a profit-maximizing oil industry operates in a perfectly competitive marketplace. The companies that comprise the industry produce gasoline and buy ethanol to create blended fuel that is then sold to consumers. Ethanol can be blended with gasoline in low-ethanol blends (E10) or high ethanol blends (E85). All vehicles can consume E10, but only flex-fuel vehicles can consume E85. Ethanol can create value for oil companies as a source of octane and oxygen and as a source of energy. Thus, ethanol

is both complementary to, and a substitute for, gasoline. Used in E10, ethanol's complementary attributes are most important because oil companies can configure their refineries to produce low octane gasoline that when blended with ethanol creates 87-octane fuel. Used in E85, ethanol's substitution attributes are most important because ethanol provides most of the energy used to power the car. Given these attributes, the derived demand for ethanol by the oil industry in E10 will be more inelastic (less price sensitive) than the derived demand for ethanol in E85.

Indirect derived demand curves for ethanol blended in E10 and in E85 are shown in Figure 1. These demand curves show the ethanol quantities that the oil industry will want to buy at various ethanol prices in the absence of mandates. The total indirect derived demand for ethanol by the oil industry is found by horizontally summing the two indirect demand curves as shown. The welfare effects of a mandate can be illustrated by adding an ethanol supply curve as in Figure 2. With no mandate, the oil industry would purchase Q_0 units of ethanol at price P_0. If faced with the obligation to buy mandated quantity, M, the price that the oil industry must pay for ethanol rises to the supply price P_S, which reflects the marginal cost of producing M units of ethanol. The demand price falls to P_D as the price must be lowered to induce consumers to buy E85. The difference, P_S - P_D, is the price of the tradable RIN. The RIN price covers the gap between the incremental cost of production and the incremental value of ethanol as a fuel.
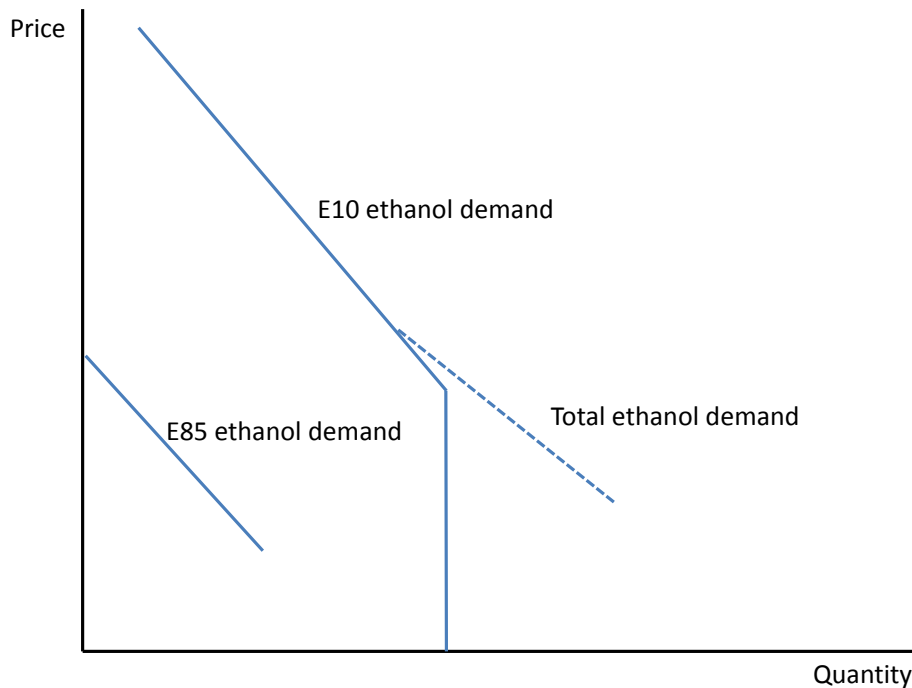
Figure 1. Derived demand for ethanol

The change in profits for the oil industry caused by an ethanol mandate is a straightforward calculation. The area under the derived demand curve and above the input price measures producer profit (Just, Hueth, and Schmitz 2005). The benefit of an input price decrease from P_0 to P_D, therefore, is the change in the area under the derived demand curve, and is given by area A+B+C. However, the oil industry does not pay a price of P_D; instead it must pay P_S for ethanol. Thus, the additional cost of ethanol, $M(P_S - P_D)$, must be subtracted from area A+B+C, leaving an oil industry loss from the

mandate equal to area D+E+F. Area D+E represents an increase in profits to the ethanol industry.[2] Much of this increase in profits to the ethanol industry will actually flow through to corn farmers through higher corn prices.
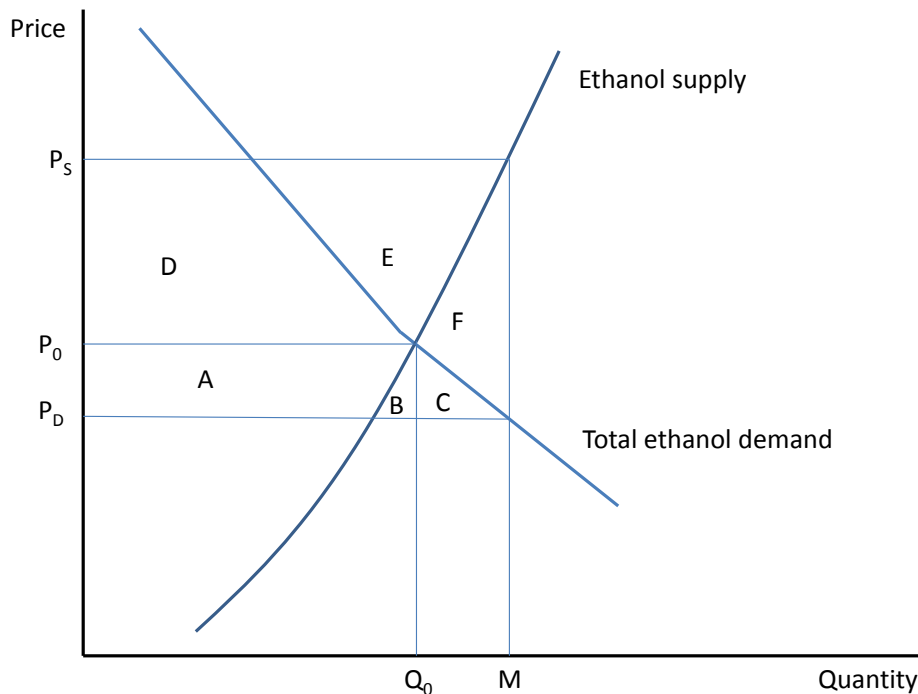
Figure 2. Welfare effects of an ethanol mandate

Losses to the oil industry seem large in Figure 2 because areas D, E, and F are large relative to area A+B+C. The steepness of the ethanol supply and demand curves along with the size of the mandate determines the size of these areas. Flatter (more elastic) demand and supply curves would lower the size of these areas substantially.

The slopes and positions of ethanol supply and demand curves can be estimated. Corn ethanol supply curves for 2014 and 2015 were estimated using current corn demand and production projections from USDA.[3] The E10 ethanol demand curve was estimated by

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[2] Area F in Figure 2 is the standard net social welfare loss of the mandate. For society to gain from this policy intervention, public benefits of extra ethanol consumption that are not shown on the diagram must be greater than area F.

[3] The ethanol supply curves are based on marketing year data rather than calendar year data. Supply and demand are calibrated to the August World Agricultural Supply and Demand Estimates issued by USDA. Corn available for ethanol production in 2014 equals total supply (14.512 billion bushels) minus non-ethanol corn demand, which consists of demand for feed, food, exports, and ending stocks. Constant elasticity demand curves were specified for feed, food, and exports with demand elasticities of -0.5, -1.0, and -0.065 respectively. Demand curves were calibrated at a price of $4.90 per bushel and a quantity of 5.1 billion bushels for feed, 1.45 billion bushels for food, and 1.225 billion bushels for exports. A nonlinear stock demand equation was specified as $600 + (1 - betacdf((MIN(Pcorn,8)/8),2.247,1.650,1,0))*3000$. This equation assumes that stock-out conditions occur at 600 million bushels at a price of $8.00 per bushel and that the maximum stock level will be 3.6 billion bushels. The supply curve of ethanol is identified by assuming that ethanol plants break-even on ethanol production, they sell distillers grains for 90

the US Department of Energy and used by the Environmental Protection Agency in their analysis of whether to grant a waiver to mandates.[4] This demand curve is best interpreted as a derived demand curve for ethanol by the oil industry. The EPA demand curve assumes that 13.5 billion gallons of ethanol can be consumed as E10. Simple arithmetic implies that this would require 135 billion gallons of total blended gasoline consumption. The latest US Energy Information Agency data on gasoline consumption shows that annual gasoline consumption has dropped from 138 billion gallons in 2010, to 134.2 billion gallons in 2011, to 133.8 billion gallons in 2012. Year-to-date consumption (through June) in 2013 is down about 1.1 percent compared to 2012, a trend that suggests that 2013 consumption would total 132.3 billion gallons.[5] To reflect decreasing gasoline consumption and the fact that not 100 percent of all gasoline will contain ethanol, the EPA demand curve is adjusted to a maximum E10 consumption of 13 billion gallons in both 2014 and 2015. A maintained assumption in this analysis is that over the next few years oil companies would maximize their profits by continuing to sell E10 to almost all consumers even without mandates if the wholesale price of ethanol is below gasoline. If this assumption is incorrect, then so too are the following calculations of compliance costs.

The demand curve for ethanol in E85 was estimated by Babcock and Pouliot (2013b) under different assumptions about future investments in E85 infrastructure and concerning physical limits on sales at E85 retail outlets. These demand curves show the quantity of ethanol that will be consumed in E85 for different wholesale ethanol prices holding fixed the price of gasoline. If we add these consumer demand curves to the oil industry derived demand curves for ethanol in E10, we then get the total quantity of ethanol that can be consumed at various ethanol prices. Figure 3 shows the 2014 estimated ethanol supply curve and the ethanol derived demand curve for 2014 assuming no new investment in E85 infrastructure and with a per-station monthly sales limit of 45,000 gallons. The price of retail gasoline was fixed at $3.60 per gallon. Without any new infrastructure investment the maximum amount of ethanol that can be sold is about 13.94 billion gallons. This quantity consists of 1.02 billion gallons of ethanol in E85 and 12.92 billion gallons of ethanol in E10. Corn ethanol production capacity was fixed at 15.2 billion gallons.

A 2015 corn ethanol supply curve was calculated based on a yield of 160 bushels per acre, which is a bit below trend yield, 85 million acres harvested, which is down 4.1 million acres from 2014, and beginning corn stocks of 1.76 billion bushels, which is 77 million bushels below what USDA projects. Figure 4 shows this supply curve along with four ethanol demand curves. Each curve corresponds to a different number of additional gasoline stations that sell E85. Each increment of 2,500 stations increases potential ethanol consumption by about 800 million gallons after accounting for the reduction in

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percent of the price of corn, non-corn variable costs of production are $0.50 per gallon and 2.75 gallons of ethanol are produced per bushel of corn.

[4] The Department of Energy's explanation for this demand curve is provided in a memo that is included in
the EPA's docket of material at http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OAR-2012-
0632-2544.

[5]These consumption numbers correspond to the US EIA variable titled "US Product Supplied of Finished Motor Gasoline."

ethanol consumption in E10 as E85 sales substitute for E10 sales.[6] Thus 5,000 new E85 stations would increase potential ethanol consumption beyond what the current US corn ethanol could produce. For reference, a sugarcane ethanol supply curve is also shown in Figure 4 for consumption in excess of the 2015 conventional biofuel mandate of 15 billion gallons.[7] As shown it will take about 5,000 new E85 stations to create potential demand opportunities for sugarcane ethanol and cellulosic ethanol if corn ethanol consumption is capped at 15 billion gallons as scheduled in the current mandate schedule in the RFS.
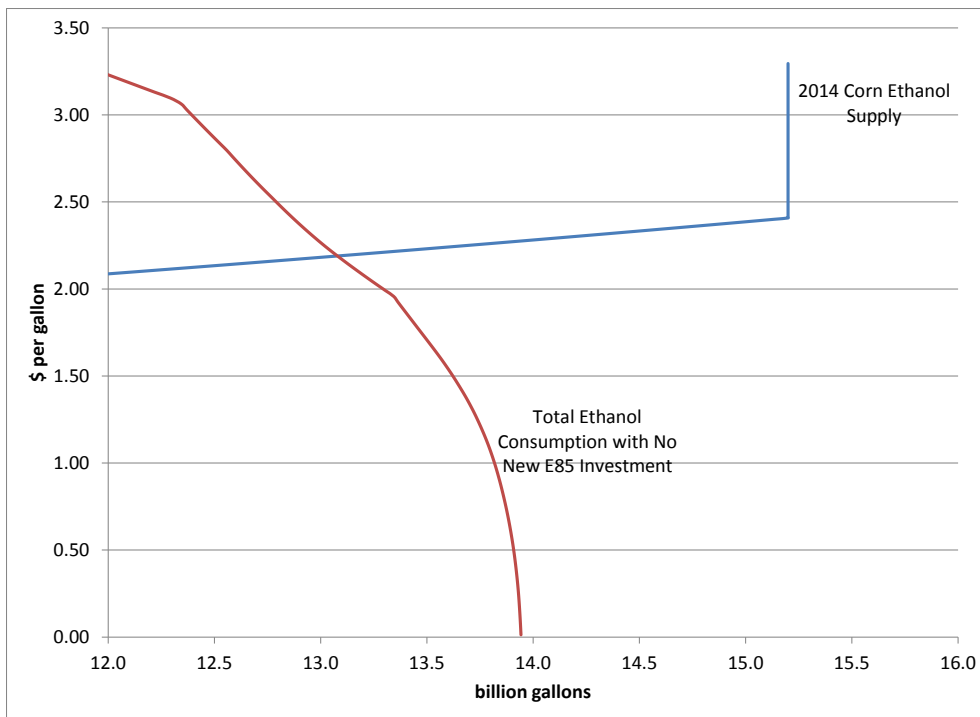
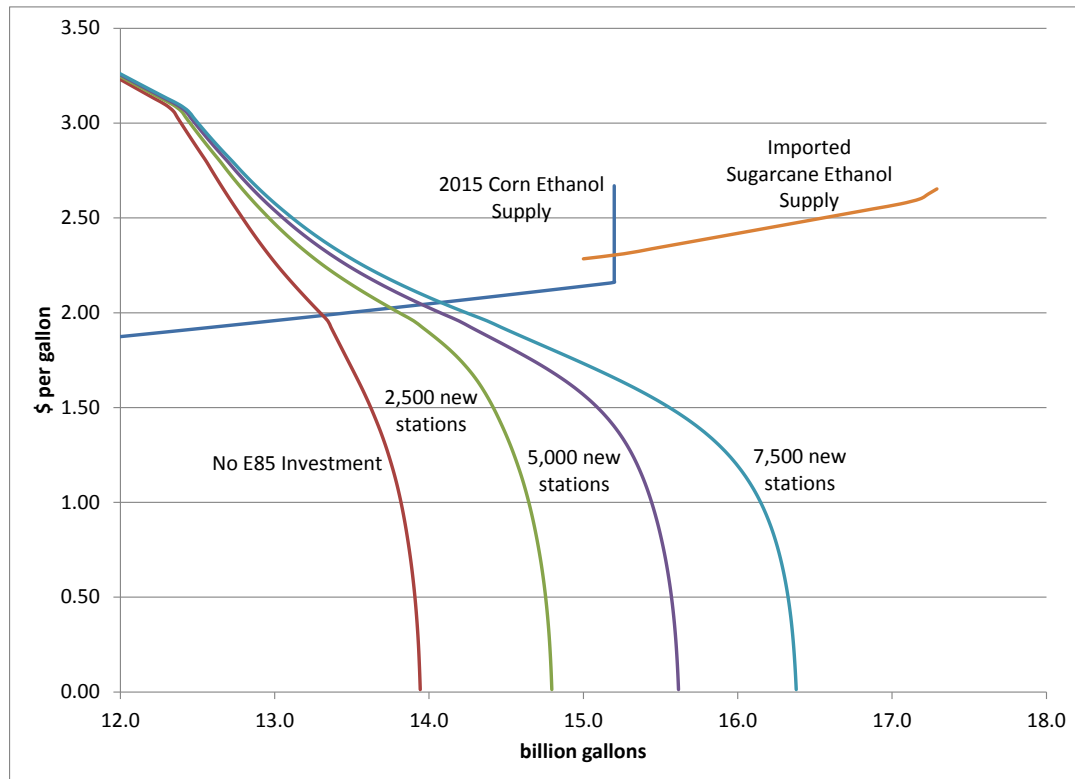**Figure 3. Ethanol supply and demand curves for 2014**

Figures 3 and 4 illustrate the problem faced by EPA in setting mandated biofuel volumes for 2014 and 2015. Without any new investment in E85 infrastructure, ethanol consumption cannot reasonably be expected to increase beyond 14 billion gallons. Total biofuel volumes then could not increase beyond 14 billion gallons of ethanol plus the amount of biodiesel that can reasonably be produced or imported and consumed. If biodiesel consumption reaches 2 billion gallons this means a total of 17 billion gallons of renewable fuels (ethanol equivalent gallons) is the upper limit on consumption. However, the RFS is scheduled to require 18.15 billion gallons of consumption in 2014 and 20.5 billion gallons in 2015. This discrepancy between what can be consumed and current RFS volumes is why EPA announced that they will consider consumption possibilities when setting biofuel volumes in 2014. If EPA specifies a total 2014 volume of 17 billion gallons, then one billon carryover RINs could possibly be used in

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[6] The portions of the Figure 4 ethanol demand curves that represent E85 consumption curves were taken directly from Babcock and Pouliot (2013b). They located the additional E85 stations according to unmet demand for E85, which corresponds approximately to the locations with the most flex vehicles per existing station.

[7] The sugarcane ethanol supply curve was estimated using the model described in Babcock, Moreira, and Peng (2013).

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combination with 14 billion gallons of ethanol and 1.333 billion gallons of biodiesel. However, in 2015, the conventional mandate is scheduled to increase to 15 billion gallons. This mandate is usually met with corn ethanol. No more carryover RINs will be available after 2014 which will make it difficult, if not impossible, to meet this volume without new investment. The set of welfare calculations presented next shed light on the incentives facing oil companies to facilitate new investment.

Figure 4. Ethanol supply and demand curves for 2015

Welfare Calculations

The key factors that determine compliance costs to an ethanol mandate are the price of ethanol that a plant needs to cover the costs of producing mandated ethanol and the price of ethanol that will induce oil companies and consumers to use up all the produced ethanol. These two prices are calculated using the demand and supply curves shown in Figures 3 and 4. The gap between these two prices is the intrinsic RIN price. Compliance costs are calculated separately for ethanol consumed in E10 and in E85. The E10 compliance costs are calculated using the derived demand curve for E10. The E85 compliance costs are calculated by assuming the oil industry gets no benefit from selling E85 that offsets the cost of RINs. Thus, oil industry costs for the portion of ethanol that is consumed in E85 equals the RIN price multiplied by the quantity of ethanol consumed in E85.[8]

The level of mandated ethanol consumption in each of the scenarios considered is net of any carryover RIN credits that are used to satisfy RFS obligations. The different

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[8] This calculation overstates compliance costs if the oil industry supply curve of E85 slopes upward. However, the change in compliance cost from investing in E85 fuel stations that is reported in Table 3 is less sensitive to this assumption.

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scenarios are defined by different combinations of year, mandate level, and demand curve. The year defines the ethanol supply curve. Table 1 shows equilibrium prices and quantities for the scenarios considered in both 2014 and 2015.

The upper limit on ethanol consumption with no new E85 investment is just shy of 14 billion gallons, so a mandate of 13.9 billion gallons is a natural starting point. The plant price that is required to produce this level of ethanol (labeled as "Plant Price" in Table 1) is $2.28 per gallon. The ethanol price that will induce this quantity of demand by the oil industry depends on whether any new investment in E85 takes place. If no new investment takes place, then the price of ethanol that induces this much consumption (labeled "Demand Price" in Table 1) is only $0.56 per gallon. If a sudden large amount of investment were to take place resulting in 2,500 new E85 stations, then the incremental value of ethanol increases to $1.96 per gallon. The difference between the plant price and the demand price is called the "intrinsic RIN price" and is reported in the last row of Table 1. The shift in ethanol demand caused by an investment in 2,500 stations reduces the intrinsic RIN price by $1.40 per gallon. This large change in the RIN price shows the impact that investment in E85 infrastructure can have in relieving consumption constraints.

Figure 5 explains why the RIN price drops by $1.40 per gallon. If 13.9 billion gallons of ethanol need to be consumed with no new investment in E85, the gap between the demand price of $.56 per gallon and the plant price of $2.28 per gallon is $1.72 per gallon, which is the RIN price as shown. An additional 2,500 E85 stations located where there exists sufficient flex vehicles would shift demand out as shown. This shift in demand dramatically closes the gap between the plant price, still at $2.28 per gallon, and the demand price. The gap shrinks to only $.32 per gallon. Figure 5 shows how shrinking the gap between the supply price and the demand price dramatically lowers the cost of complying with a 13.9 billion gallon mandate.
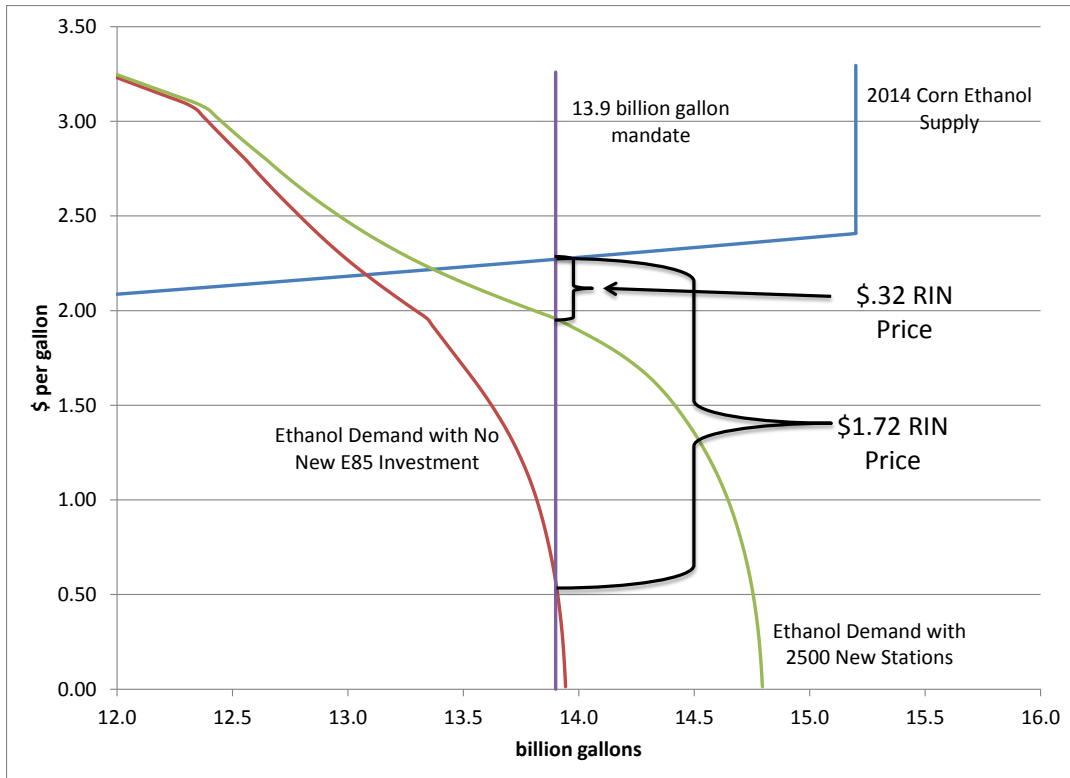
Figure 5. Impact of 2,500 new E85 stations in 2014

The no investment scenario in 2014 gives a good idea of what would happen in 2015 with no new investment, so the 2015 scenarios begin with 2,500 new stations and a mandate of 14.7 billion gallons, which is close to the upper limit on consumption with the new stations. Scenarios defined by investment increases to a total of 5,000 and 7,500 new stations will demonstrate the effects of an additional ramp-up of investment. Two additional scenarios show what will happen with a more aggressive EPA mandate of 15.5 billion gallons coupled with large investments in E85 infrastructure.

Table 1. Scenarios, Prices, and Quantities

Year	2014	2014	2015	2015	2015	2015	2015
Mandate	13.9	13.9	14.7	14.7	14.7	15.5	15.5
Demand Curve[a]	+0	+2500	+2500	+5000	+7500	+5000	+7500
No Mandate Price	2.19	2.22	1.99	2.05	2.06	2.05	2.06
No Mandate Quantity	13.07	13.36	13.3	13.93	14.0	13.9	14.0
Plant Price	2.28	2.28	2.12	2.12	2.12	2.20	2.20
Demand Price	0.56	1.96	0.79	1.74	1.84	0.82	1.52
Demand at Plant Price	12.98	13.26	13.14	13.74	13.88	13.59	13.71
Intrinsic RIN Price	1.72	0.32	1.33	0.38	0.28	1.38	0.68

Notes: All prices are expressed in dollars per gallon.
[a]Demand curves are defined by the number of new E85 stations. So "+2500" means that 2,500 new stations sell E85.

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Table 2 shows the losses (compliance costs) to the oil industry and gains to the ethanol industry for each of the scenarios. [9] Also reported is the total value of RINs, and as can be easily seen, the total value of RINs is many times greater than oil industry compliance costs. In the two 2014 scenarios considered, RIN revenues are between 4 and 8 times greater than losses to the oil industry, which total $2.84 billion under the no-investment demand curve and about $1.09 billion when 2,500 new stations are installed. These results show why it is wrong to use the total value of RINs as a measure of the cost of complying with RFS mandates. A compliance cost of $2.84 billion amounts to 2.2 cents per gallon of fuel if 130 billion gallons of blended gasoline are consumed.

The impact of investing in E85 is shown in Table 3. For example, the first column in Table 3 shows that investing in 2,500 stations in 2014, conditional on a mandate of 13.9 billion gallons and given the 2014 ethanol supply curve, would reduce compliance costs by $1.75 billion, which is calculated from Table 2 by subtracting 2014 compliance costs with 2,500 new stations from compliance costs without the new stations. Of course, obtaining these reductions in compliance costs requires investment in E85 equipment. In stations that convert an existing tank to E85, the cost of conversion is approximately $30,000 per station. The cost of adding a new tank and a dispenser is approximately $130,000 (EPA 2010).

If oil companies pay for the installation of E85 equipment, then the total investment cost for all 2,500 stations reduces the benefits they receive from lower compliance costs. At the $30,000 cost per station, oil companies would still have a net gain of $1.7 billion. Net gains drop to $1.4 billion at the much higher $130,000 per station cost. The benefit-to-cost ratio from investing in E85 infrastructure would be more than 5 to 1 with the $130,000 cost per station. These results show that if EPA adopts a mandate for 2014 that can be met by blending 13.9 billion gallons of ethanol, then oil companies would have a large enough financial incentive to actually pay for the E85 infrastructure that would increase demand for ethanol.

The results from the other scenarios show that the payoff to oil companies from investment in E85 infrastructure, in terms of reducing their cost of compliance with mandates, depends greatly on where EPA sets the mandate relative to the existing amount of infrastructure. When the mandate is set at a level that is not easily met with existing infrastructure, then the incentive to invest in infrastructure is large. When the mandate is set at a level that can readily be met, then the incentive is much smaller. For example, with the 2015 ethanol supply curve, a 14.7 billion gallon mandate, and assuming that 2,500 new E85 stations were added in 2014, adding another 2,500 stations reduces oil industry compliance costs by more than $2.4 billion. This investment would reduce RIN prices from $1.33 per gallon to $0.38 per gallon (Table 1). Investing in yet another 2,500 stations with this mandate would only reduce RIN prices by another 10 cents. Compliance costs would be reduced by this investment (bringing the total number of new stations to 7,500) but by only $302 million. This level of benefit would create a smaller investment incentive. If EPA were to anticipate that 5,000 new stations

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[9] It is simple to calculate the standard deadweight loss triangle from a mandate from the results in Table 2. It simply is the loss to the oil industry minus the gain to the ethanol industry. Any public benefits from expanded ethanol consumption that explain why the Renewable Fuels Standard exists would need to be added to this deadweight loss triangle to determine the net social welfare effects of the mandate.

[10] See page 3 of answers from John Askounis of Phillips 66, to "Questions for Stakeholder Comment" from the House Committee on Energy and Commerce.

would have E85 capability, then it could increase the 2015 mandate to 15.5 billion gallons. This level of mandate would restore the large incentive to invest with E85 capability, as indicated by the last column of results in Table 3.

Table 2. Welfare Calculations

Year	2014	2014	2015	2015	2015	2015	2015
Mandate	13.9	13.9	14.7	14.7	14.7	15.5	15.5
Demand Curve	Current	+2500	+2500	+5000	+7500	+5000	+7500
Loss to Oil Industry	2,840	1,089	4,011	1,564	1,262	5,431	3,535
Gain to Ethanol Industry	1,214	818	1,820	1,002	861	2,207	2,065
RIN Revenue	23,908	4,448	19,551	5,586	4,116	21,390	10,540

Notes: Measurement units are billion gallons for the mandate and million dollars for all monetary amounts. Demand curves are defined as in Table 1.

Table 3. Incremental Impact of Adding 2,500 E85 Stations

	Scenario			
	2014 Add 2500 to Current Stations	2015 Add 2500 to total 5000	2015 Add 2500 to total 7500	2015 Add 2500 to total 5000
Mandate (billion gallons)	13.9	14.7	14.7	15.5
Reduction in oil company loss				
Gross Change	1,751	2,447	302	1,896
Change Net of Investment Cost				
$30,000 per-station cost	1,676	2,372	227	1,821
$130,000 per-station cost	1,426	2,122	(23)	1,571
Benefit-Cost ratio				
$30,000 per-station cost	23.4	32.6	4.0	25.3
$130,000 per-station cost	5.4	7.5	0.9	5.8

All welfare calculations expressed in millions of dollars.

Implications

Ethanol consumption can be increased significantly beyond 13 billion gallons only with significant new investments in E85 infrastructure. The need for new infrastructure to allow for increased biofuel consumption is similar to the situation in 2007 when new infrastructure was needed to allow E10 consumption in all parts of the country. The required E10 investment was carried out by 2010 because of two incentives. First, industry was convinced that E10 throughout the country would be needed to meet scheduled increases in mandates. There really was no uncertainty about whether mandates would be met. Second, E10 infrastructure investments had very high rates of return because the blenders tax credit created such a strong incentive to maximize ethanol use. Ethanol consumption exceeded mandate levels until 2012, when drought in the Corn Belt increased ethanol production costs.

The blenders tax credit, however, no longer exists. Now the only incentive to invest in infrastructure is to reduce compliance costs. A subsidy to increase biofuel consumption has been replaced with a tax on oil companies that penalize them for a failure to blend. The size of the tax is measured by the level of RIN prices. The results presented here indicate that large incentives to invest in the infrastructure that can reduce compliance costs can be created only if EPA sets mandates at levels that will result in high RIN prices if no investments are made. Only if sufficient incentives are created by high RIN prices will the E85 infrastructure investments be made. The investments will lower RIN prices and thus lower oil company compliance costs.

RFS mandates place the oil industry in a difficult situation. On the one hand, the industry has an incentive to reduce compliance costs by investing in infrastructure that increases the demand for biofuels. However, in making these investments, the industry is reducing the demand for its own product, gasoline. Clearly the best situation for the oil industry is to have EPA not push mandates above the quantity of ethanol that maximizes their profits. This explains the effort that the industry is currently undertaking in Congress and through petitions to EPA to revise mandates downward. If successful, it is likely that ethanol consumption will stay at about the level that can be consumed with E10 and that there will be little incentive to invest in new E85 stations.

If the oil industry lobbying effort is unsuccessful then EPA has the tricky task of choosing mandate levels. If EPA sets mandates that are easily met, then the incentive to invest in infrastructure will be low. Thus, the infrastructure that will facilitate consumption of even larger amounts of ethanol in the future will not be built. If EPA sets mandates at too high a level, then it risks disruption in fuel markets because of the difficulty of meeting the targets in a timely manner. This situation argues for clear signals from EPA about what they plan to require over the next few years because the cost of matching investment to achieve desired consumption targets will be lower if adequate time is given for the investments to be undertaken.

The RFS contains one clear roadmap for future mandates; however, this roadmap cannot be met because cellulosic biofuel supplies will not come close to the volumes specified. EPA has signaled that they recognize this reality and the reality that current infrastructure will not allow enough biofuel consumption to meet scheduled increases in mandates. But EPA has not provided unambiguous signals about the level of investment that will be needed for future compliance.

Reality vs. Abstraction
This analysis simplifies the fuel production and distribution business by treating the oil industry as a vertically integrated refiner, blender, and retailer; however, reality is quite different. Some oil companies only own refineries, others are both refiners and blenders, some own ethanol plants, and some do indeed refine, blend, and sell at the retail level, although the proportion of retail stations owned by obligated parties is only about 5 percent.[10] The pertinent question is whether accounting for this reality changes the conclusions of this study.

Suppose that the parties who are obligated to meet the mandates only refine crude oil into gasoline and other products. The gasoline is sold to independent blenders who also

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[10] See page 3 of answers from John Askounis of Phillips 66, to "Questions for Stakeholder Comment" from the House Committee on Energy and Commerce.

buy ethanol from ethanol plants. Blenders combine gasoline and ethanol into finished motor fuel. Blenders sell the finished fuel to independent retailers who then sell the fuel to consumers. In this model, obligated parties do not have a derived demand for ethanol because they do not use ethanol in their production process. Rather blenders have a derived demand for ethanol because they blend ethanol with gasoline to produce finished motor fuel. In addition, when blenders buy ethanol they also are buying the RIN that travels with the ethanol. Blenders separate the RIN from ethanol when it is blended. Thus, blenders supply RINs and obligated parties demand them, and trade occurs in the RIN market.

The price of RINs will increase if the demand for RINs exceeds supply. This will occur, for example, if EPA suddenly announces 2014 mandates that can only be met if ethanol consumption exceeds 14 billion gallons. An increase in the price of RINs increases both the price of existing RINs that are owned by those lucky enough to be sitting on banked RINs, but also the value of any new RINs generated by owners of ethanol plants. Blenders will want to buy more ethanol from plants to acquire the more valuable RINs. However, blenders will not buy more ethanol if there is no way to sell it to consumers. In this case, the supply of RINs will not increase because blenders simply have no place to sell the additional ethanol that is supplied with the valuable RINs. A lack of a RIN supply response will mean even higher RIN prices from the increase in RIN demand; and higher RIN prices mean even higher compliance costs to obligated parties.

The solution to this problem offered by some oil companies is that they will simply sell less gasoline in the United States.[11] A gasoline producer's Renewable Volume Obligation (RVO) equals a percentage standard set by EPA multiplied by the amount of gasoline that the producer sells in a year. Suppose that a producer plans on selling 10 billion gallons of gasoline and the percentage standard is 11 percent. This producer would need to buy 1.1 billion RINs to meet its obligation; but a problem arises if this producer can only buy 1.0 billion RINs. One way to comply with the obligation is to only sell 9.09 billion gallons of gasoline because the product of 11 percent and 9.09 billion gallons is 1.0 billion RINs. Presumably, the 910 million gallons of gasoline not sold in the United States would be exported.

Consider, however, what would happen in the gasoline and ethanol markets if this drop in domestic sales actually occurred. If all obligated parties followed this compliance scenario and decreased domestic gasoline sales by the same percentage amount, then the price of gasoline would increase substantially. With a demand elasticity of -0.2, and a reduction in sales of 9 percent, the wholesale price of gasoline would increase by 45 percent from say, $2.80 per gallon, to more than $4.00 per gallon. This domestic price increase would dramatically increase the price disadvantage of selling gasoline in the export market because the net price received for exported gasoline would be $2.80 per gallon minus transportations costs, assuming that the additional exports did not depress world gasoline prices. Furthermore the steep rise in gasoline prices would increase the demand for ethanol. Imagine the incentive that would be created to substitute $2.00 ethanol for $4.00 gasoline. This incentive would result in investment in E85

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[11] For example, John Askounis from Phillips 66, in a written response (page 3) to "Questions for Stakeholder Comment" from the House Committee on Energy and Commerce stated "Once the blend wall is hit and there is no practical way to increase the volume of ethanol in the gasoline supply, obligated parties will look for ways to reduce their RIN obligation through reducing their gasoline and transportation diesel volumes (through lower refinery production, increased exports, or a combination).

infrastructure just as the large rate of return to E10 investment resulted in the build-out of the E10 infrastructure in the late 2000s. Investment in this infrastructure would then allow blenders to buy more ethanol from plants, which would increase ethanol consumption, increase the supply of RINs, and thereby allow obligated parties to more easily meet their obligations. An example will show why this market response makes the oil company compliance scenario unlikely.

Suppose that all but one of the oil companies decide to reduce domestic sales of gasoline. The one that decides not to follow this path is a modest-sized oil company with 5 billion gallons of gasoline production sales, and thus needs 550 million RINs to comply with the RFS. This company finds itself in the same situation as not being able to buy enough RINs but instead of reducing domestic gasoline sales by 9 percent (450 million gallons) this company enters into an agreement with independent retail gasoline stations to invest in their ability to sell E85. In addition, the company signs a separate agreement with a blender/distributor that the RINs generated by sales of E85 to these stations would be sold back to the oil company at a mutually agreeable price. Further suppose that the initial agreement was with 150 strategically located stations and the average cost of the infrastructure was $60,000 per station for a total cost of $9 million. If all the other oil companies decrease domestic gasoline sales except this one, then these 150 stations could sell all the E85 that they could manage because the price of E85 would be so much lower than the inflated price of gasoline. If the physical limit on E85 sales were 50,000 gallons per month, then total annual sales at these 150 stations would be 90 million gallons of E85, or about 75 million gallons of ethanol. This represents 75 million additional RINs, which is 25 million than more than needed for compliance. So for an investment cost of $9 million, this company would not lose out on the ability of selling 450 million gallons of gasoline at the much higher domestic price, and it would be in compliance with the RFS because of increases in E85 sales. With a domestic price of $4.00 per gallon and an export price of $2.80 per gallon, the ability to sell the 450 million gallons domestically would generate additional revenue of $540 million. All for an investment of $9 million. Of course, if one oil company figured this out, then every other oil company would figure this out and no company would find it profitable to reduce gasoline sales in the United States. This example shows that this study's simplified treatment of industry structure leads to the same conclusion as a more nuanced treatment.[12]

Conclusions
If the oil and livestock industries fail in their attempt to limit biofuel consumption to easily attainable levels, then new investment in E85 and E15 infrastructure must occur. This is not news. EPA (2010) estimated that compliance with RFS2 mandates would require between $1.526 and $4.973 billion in new E85 retail structures by 2022, depending on the amount of ethanol used to meet mandates. The question becomes not whether the investment is needed, but rather the pertinent questions are who will make the investments and whether strong enough incentives are created by RFS2 enforcement mechanisms to make sure that investments take place.

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[12] If less-than-perfect competition characterizes the relationships between retailers, blenders, and oil refiners, as it likely does at least in the short run, then the oil company compliance costs reported in Table 2 can best be interpreted as the sum of compliance costs across these three types of firms. Bargaining power between them will determine the actual distribution of compliance costs from a mandate.

One possibility is for taxpayers to pay for the cost. Justification for taxpayers to pay is that because the public benefits of using renewable fuels are broadly shared then the costs should be as well. One way for taxpayers to pay for the investment without increasing overall federal spending is to divert farm subsidies from corn farmers. Corn farmers have been a primary beneficiary of ethanol expansion and they have been enjoying record income levels for some time; and yet, even though their profits have been at record levels corn farmers continue to receive large subsidies. Direct payments total $2 billion per year and in 2012 taxpayers spent more than $3.5 billion subsidizing the delivery and purchase of corn farmers' crop insurance. One would think that given a choice, corn farmers might opt to spend some portion of that $5.5 billion on installation of E85 or E15 infrastructure. At $130,000 per station, $5.5 billion could convert more than 40,000 stations. Conversion of this many stations would immediately transform the current problem of too few renewable fuel outlets to one of too little renewable fuel.

Another possibility is for owners of retail gas stations to bear the costs. Stations owners will make investments in E85 if they can make enough additional money from E85 sales to justify the investment. This will require a low-enough wholesale price of E85 to support higher wholesale-to-retail markups for E85 than for E10, as well as low-enough E85 retail prices to save consumers money on their motor fuel bill. High RIN prices are the mechanism to accomplish this task because they give blenders the incentive to buy more ethanol to obtain RINs to sell to obligate parties. If E85 is the only way to sell additional ethanol, then blenders will need to price E85 low enough to stimulate sales. If mandates are high then RIN prices will have to be high enough to stimulate not just sales at existing stations but also new investments by station owners.

It is unlikely that taxpayers or corn farmers will step up to make the required investments in renewable fuel infrastructure; and high RIN prices may not work fast enough to induce enough investment by independent station owners to allow oil companies to meet their obligations. In this case, the obvious alternative is for oil companies to lower their own compliance costs by making the investments for them. The results of this study suggest that the rate of return on this investment in terms of lower compliance costs could be large enough and predictable enough to actually make such investments attractive.

Creation of financial incentives to induce companies to make investments that meet public policy objectives is how market-based policy instruments work. Nobody expects the companies who have to make the investment to enjoy it. However, the goal of expanding renewable fuel is to reduce consumption of fossil fuels. It is no surprise that companies who produce fossil gasoline would object to the long-run financial impact of reduced demand for their product, even if in the short-run it makes financial sense for them to facilitate that reduction in demand.

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