THE RENEWABLE FUEL STANDARD:

HOW MARKETS CAN KNOCK DOWN WALLS

By

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

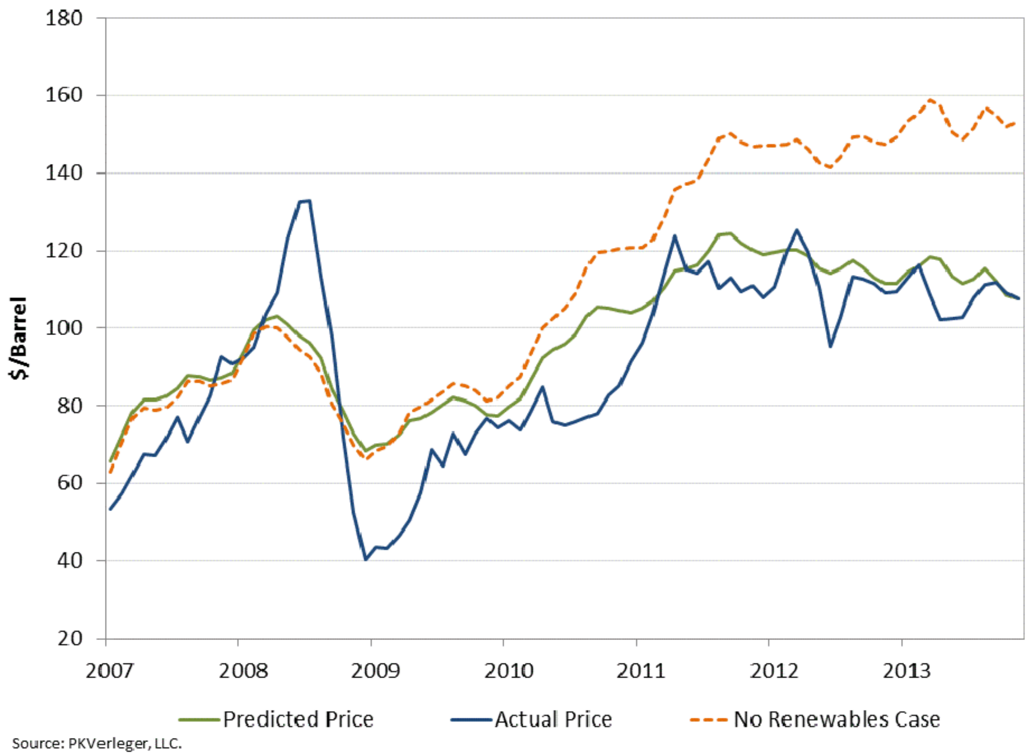
Most motorists don't realize that they are the beneficiaries of a significant policy experiment that began several years ago during the Bush Administration, although they may have noticed signs at nearly all fuel pumps indicating that the gasoline contains up to 10% ethanol, called E10 by the fuel industry. The policy that helped make 10% ethanol the market norm—the Renewable Fuel Standard (RFS)—has helped moderate overall fuel prices and will continue to do so if given a chance to evolve in a way that preserves its basic structure.

The RFS requires a certain percentage of ethanol be blended into motor fuel, and creates a credit pricing system to rationalize that process. The price of these credits—called Renewable Identification Numbers or RINs—spiked last year, causing much consternation in oil markets and in some policy circles in Washington. Nevertheless, even that episode showed that the basic policy works as intended, insofar as the higher RIN prices stimulated a substantial jump in sales of 85% ethanol gasoline blends (E85) purchased by owners of flex-fuel vehicles (FFVs). Cheered on by some segments of the oil industry, however, the Obama Administration proposed a retreat from the ethanol percentage requirements for 2014, apparently spooked by the prospect that high RIN prices might be blamed for high gasoline (E10) prices or some unspecified distortions in the market. This is particularly ironic, given that the RIN price is the primary vehicle for stimulating additional ethanol use to achieve the objectives of the program, and that the overall impact of the program is to reduce U.S. gasoline prices.

This concern regarding the effects of RIN prices on motorists is misguided and clearly refuted by market evidence. Our examination of the interplay between the RFS policy and transportation fuel markets shows that:

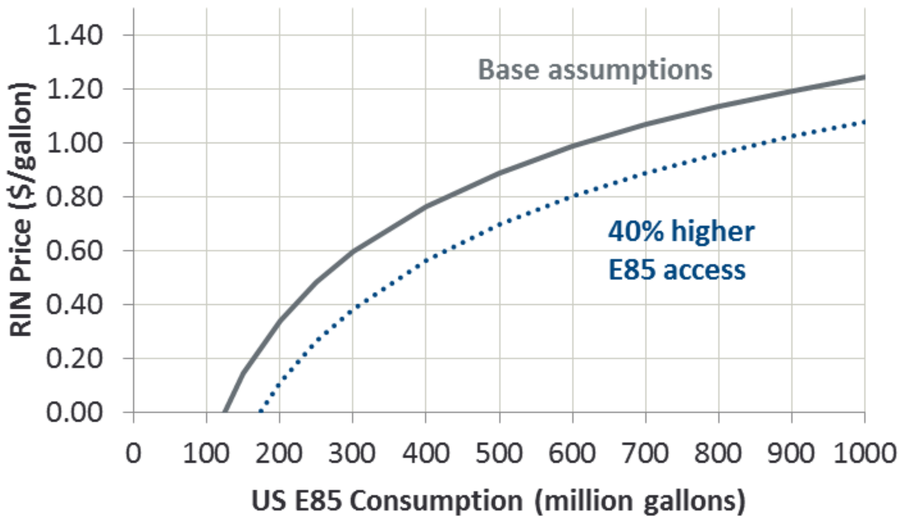
Ethanol use lowers crude oil prices. Continued tightness in world oil markets means that any reduction in U.S. crude oil demand—through more efficient vehicles, more conscientious driving habits or ethanol blended into motor fuels—will have a disproportionate impact on world oil prices. In the case of ethanol, we estimate that overall cumulative ethanol consumption since 2007 has reduced the current crude price by about $45 per barrel, or about $1.00 per gallon, as shown in Figure ES-1. The effect on crude oil price due to the volumes blended in 2013 alone (above 2007 levels) are responsible for a $10 per barrel crude oil price reduction from the actual price observed, or about 25¢ per gallon. Thus, motorists reap the benefit of lower overall fuel prices, *even if* RIN prices temporarily work their way into retail E10 gasoline prices. The RFS policy represents a win for consumers.

Figure ES-1: Actual Brent Prices, Predicted Brent Prices and Predicted Brent Prices Without Renewables



RIN prices work as intended. The pronounced jump in E85 sales observed in mid-2013 was a result of higher RIN prices, and demonstrates conclusively that when retailers discount the price of E85 compared to E10 (regular gasoline) to reflect the higher value of RINs, owners of flex-fuel vehicles respond by filling up their tanks with E85. The data from Minnesota shows that for every percentage point reduction in the ratio of E85 to E10 price, sales volumes of E85 rise by over 5 percent. This directly contradicts the oil industry's claim that E85 cannot be effectively marketed to the nearly 15 million flex-fuel vehicle owners. Using conservative assumptions regarding the current status of accessibility and marketing of E85, as well as competitive pricing by the oil industry, we estimate that a RIN price of about $1.00 would induce sales of about 600 million gallons of E85 from the existing FFV fleet. This would not negatively impact the price of regular (E10) gasoline. If E85 marketing improved and infrastructure expanded as a result of a growing RFS mandate, RIN prices could be significantly lower at any given level of E85 sales, as shown on Figure ES-2.

Figure ES-2: RIN Prices and E85 Consumption Under Base Assumptions and Greater E85 Access



RIN price impact on retail gasoline (E10) prices is small and transient. The retail price of gasoline depends on myriad factors that affect a complex web of transactions from refineries purchasing crude oil to blender/distributors marketing finished gasoline-ethanol blends to service stations. Over time, competition in these interrelated markets tends to drive out any windfalls that may emerge when refiners or blenders try to embed the RIN price into regular gasoline (E10) prices. However, regular gasoline prices probably were affected by the RIN prices observed during 2013, by about 5¢ to 6¢ per gallon at most, an amount comparable to typical weekly average price changes. This effect would diminish as competition at the retail distribution level strengthens under a more predictable RIN price trajectory.

What of the so-called "blend wall" that supposedly prevents additional volumes of ethanol to be cost-effectively introduced into the vehicle fuel markets? While some infrastructure and market constraints do exist, the empirical evidence suggests that the blend wall is neither impossibly high nor impenetrable. It is more accurately described as a "blend step" that reflects the current constraint for conventional vehicles (*e.g*, 10% ethanol limit for fuel), but it is not an insurmountable barrier to achieving higher levels of ethanol use when RIN prices work to stimulate significant demand for E85 from the flex-fuel fleet. The increased demand levels for E85 enabled by RIN prices creates the market incentive to invest in additional E85 infrastructure. Thus, the blend wall can be overcome by letting the RFS policy work as intended through RIN price levels sufficient to attract additional investment, encourage innovative pathways and expand choices for vehicle fuels.

I. RENEWABLE FUELS HAVE SIGNIFICANTLY REDUCED GLOBAL CRUDE OIL PRICES

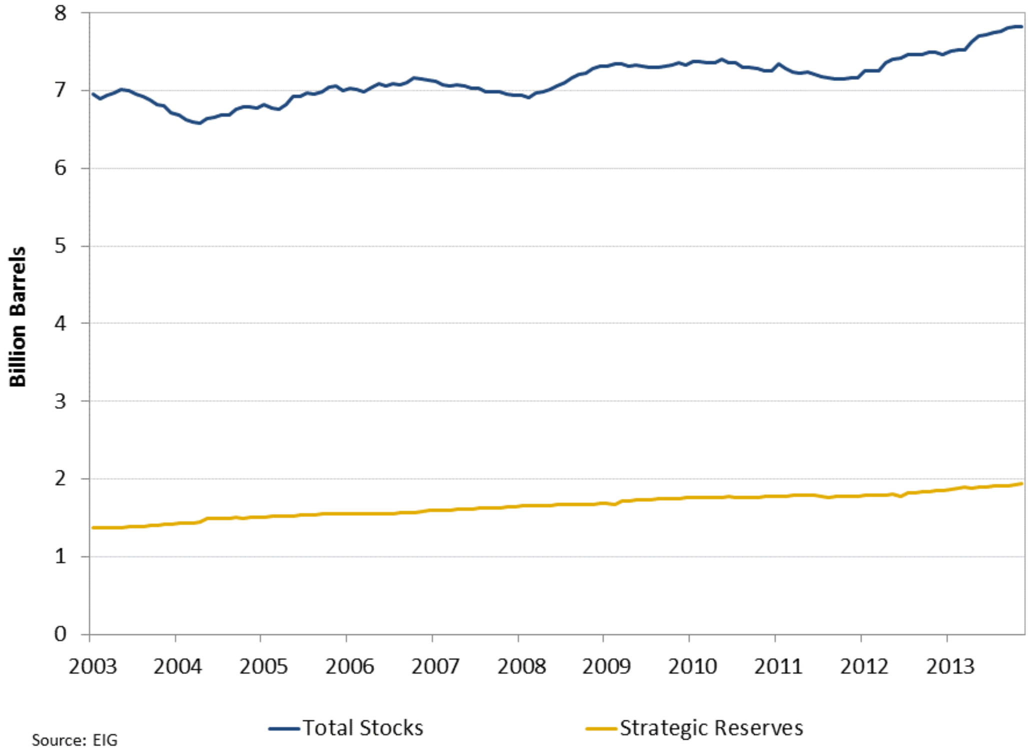
Policy debates frequently focus on a narrow set of issues and lose sight of the big picture. In the debate surrounding the 2014 renewable volume obligation (RVO), the overall benefits of the program have been obscured while various factions argue over the incidence of costs. In this section we return to the original intent of the program, which was to reduce the U.S. dependence on imported oil and mitigate some of the economic burden associated with high oil prices.

The Model

In order to assess the impact of the renewable fuel standard (RFS) program on consumer gasoline prices, we construct a model of global crude oil prices. Ethanol use in the U.S. has removed a substantial portion of crude oil demand from the world market, which, under the tight supply environment over the past several years, has produced a material reduction in price. The model calculates the Dated Brent (DB) oil prices that would have prevailed "but-for" the RFS program using an econometric approach that relates changes in DB prices to changes in inventories and seasonal variables.

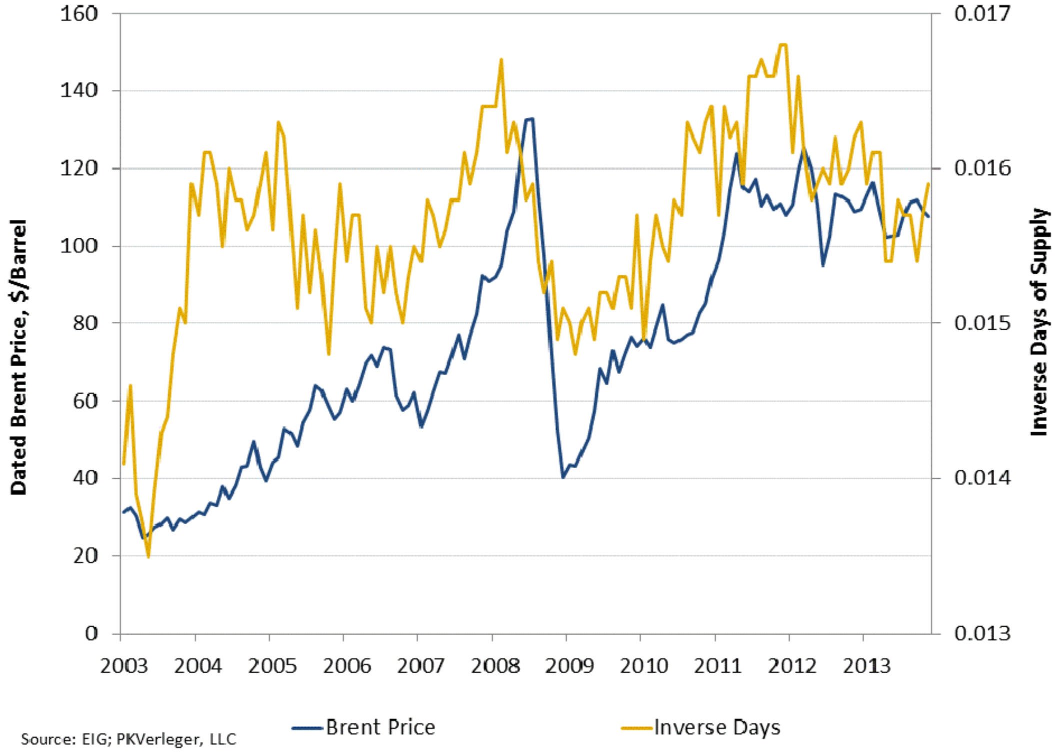
Energy Intelligence Group (EIG) publishes detailed data on inventories held across the globe and enables analysts to separate commercial inventories from strategic stocks. Figure 1 shows data on total global stocks and strategic stocks. Governments control strategic stocks, which account for approximately 16% of global inventories. Experience shows that these stocks have been "sterilized," that is, they are never used and therefore do not factor into price formation. In this study we compare the movement of commercial stocks and prices. For analytical purposes, we compare the price movement with the inverse of stocks relative to consumption.

Figure 1: Monthly Global Commercial and Strategic Inventories of Crude Oil and Products, 2003–2013



The ratio of stocks to consumption indicates the days of supply of available inventories. Economic theory would predict that a rise in inventories relative to consumption would lead to lower prices, all other things being equal. Using inverse days of supply as the inventory measure, one would expect to see prices rise when inverse days rise and fall when inverse days decline. Figure 2 compares inverse days of supply with the estimated DB price, which visually depicts how the two series tend to move together. The first task in providing statistical support for what Figure 2 indicates is to identify the empirical linkage between changes in the inverse of global days of commercial inventory coverage and changes in prices.

Figure 2: Inverse Days of Commercial Supply vs. Dated Brent Price
January 2003 to November 2013



To accomplish this, we regressed monthly data on the crude price change on the change in a sequence of current and lagged values of inverse days of supply and seasonal dummy variables. The equation took the form:

$$\Delta Pt = \alpha + \beta 1\ \Delta(1/dayt) + \beta 2\ \Delta(1/dayt\text{-}1) + \beta 3\ \Delta(1/dayt\text{-}2) + \beta 4\ \Delta(1/dayt\text{-}3) + \beta 5\ JA + \beta 6\ MA + \varepsilon$$

P_t represents the DB price; 1/day represents the reciprocal of commercial days of supply with the subscript identifying days of supply at the end of the current month (current consumption divided by end-of-month stocks), the previous month, two months previous, and three months previous; and JA is a dummy for the January-April period and MA for the May-August period. The parameters α and β_1 through β_6 are estimated using standard statistical techniques.[1]

[1] Through empirical testing, we determined that the month-to-month price fluctuations were affected differently during three 4-month seasonal periods: January to April, May to August, and August to December. Additional empirical testing indicated that the change in inverse days of supply in the current month as well as the three previous months also influenced the crude price change. The lags may reflect a pass-through of information similar to what is also observed in retail petroleum markets.

We estimated the model using the monthly data shown in Figure 2 for the period 2006 through 2013. Table 1 lists the estimated parameters and the standard summary statistics.

Table 1: Estimated Parameters and Summary Statistics for Inverse Days of Supply Price Model

Parameter	Coefficient	Standard Error	t-Statistic
α	-2.3		
β_1	5,203.5	2,562.0	2.03
β_2	8,432.2	2,731.8	3.09
β_3	6,379.7	2,694.1	2.39
β_4	3,003.0	2,440.4	1.23
β_5	5.2	1.7	3.08
β_6	2.8	1.7	1.69

$R^2 = 0.183$

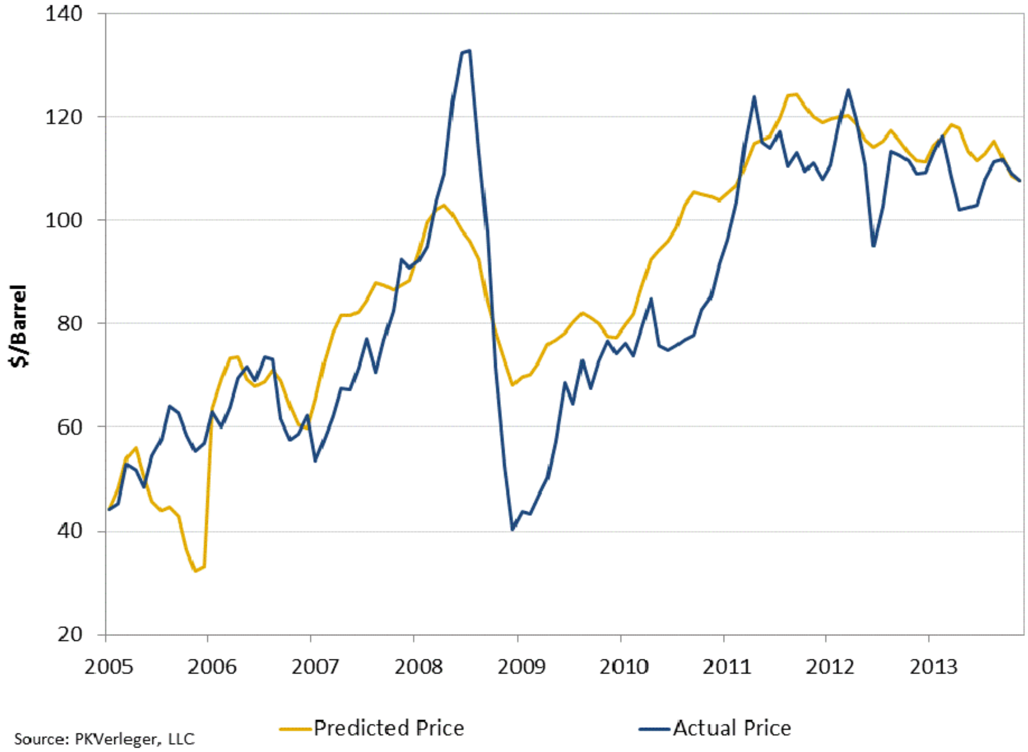
Standard Estimate = $6.69 per barrel

Source: PKVerleger LLC.

We tested the model using an iterative process that predicted the price level based on the model's forecast of the price change from period to period. We did not correct for errors. We calculated the predicted price for period t, Pt*, using the prediction for the prior period, Pt-1*, plus the prediction of the price change from t-1 to t generated by the model.

Figure 3 shows the model's prediction of DB prices. As the graph illustrates, the model did a reasonable job of predicting the DB price when the forecast was generated using the iterative process. The prediction explained 80% of the price variance without correcting for errors, and predicted prices tracked actual prices closely between 2011 and 2013. In fact, the November 2013 DB price predicted by the model under observed conditions was $107.60 per barrel, almost exactly the price reported in the market.

Figure 3: Actual Dated Brent Prices vs. Predicted Brent Price Based on Inverse Days of Supply 2005–2013



Source: PKVerleger, LLC

Our results confirm that commercial inventories are an important predictor of price changes and price levels. A decline in stocks (which would cause days of supply to fall and inverse days of supply—the equation's explanatory variable—to rise) would be expected to boost prices. The magnitude of the increase would depend on the days of coverage. In this model, there is a nonlinear relationship between inventories and days of supply, with lower stock levels leading to larger price increases than higher stock levels. This finding is consistent with most economic research.

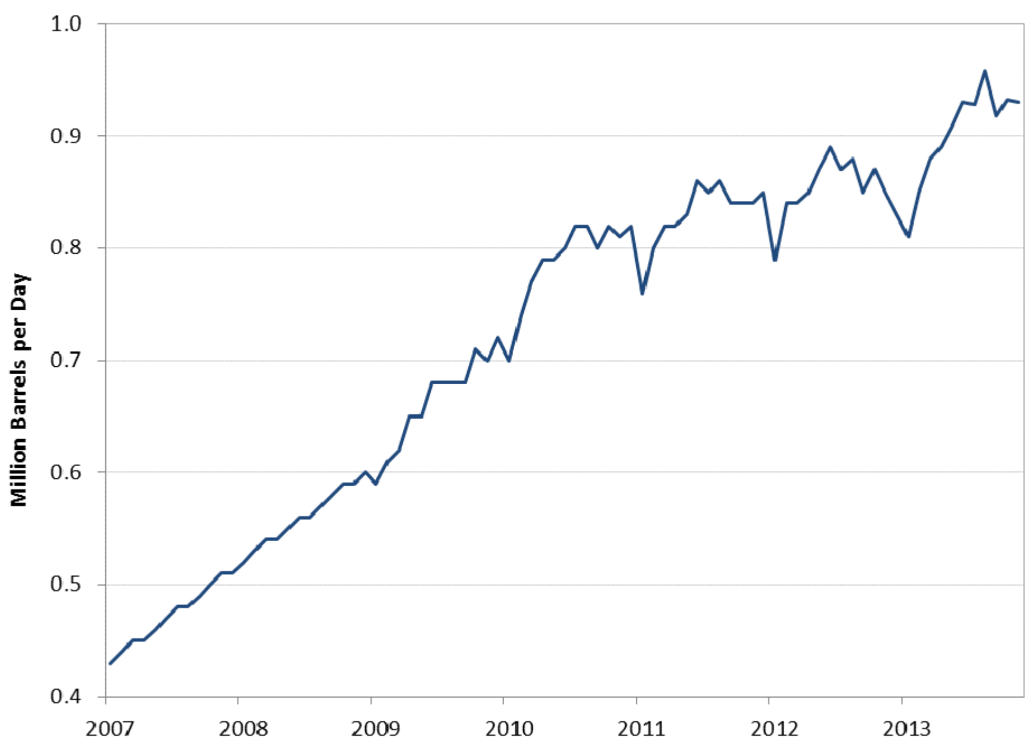
As a final point, we add that government stocks do not influence prices. We tested the model with a measure of government inventories—the days of coverage offered by these stocks—as an additional explanatory variable. The coefficients on the government stocks were all statistically insignificant. This result should not come as a surprise, as many analysts have noted that the management of public oil stockpiles has been terribly inept, and the data reveal that market participants pay no attention to changes in public crude oil holdings.

Estimating the Effect of Renewable Fuels

We next used the model to simulate the crude price impact of the U.S. renewable fuels program. We examined the impact of the U.S. renewable fuels policy on crude prices by asking: "What would happen to the world crude oil price benchmark (the DB price) if the ethanol volumes introduced into U.S. motor fuels had not occurred?" We conducted this "what-if" experiment assuming the amount of oil available to global consumers would have been lower absent the amount of petroleum displaced by U.S. ethanol use. In other words, energy from ethanol has been equivalent to a marginal supply of crude oil.

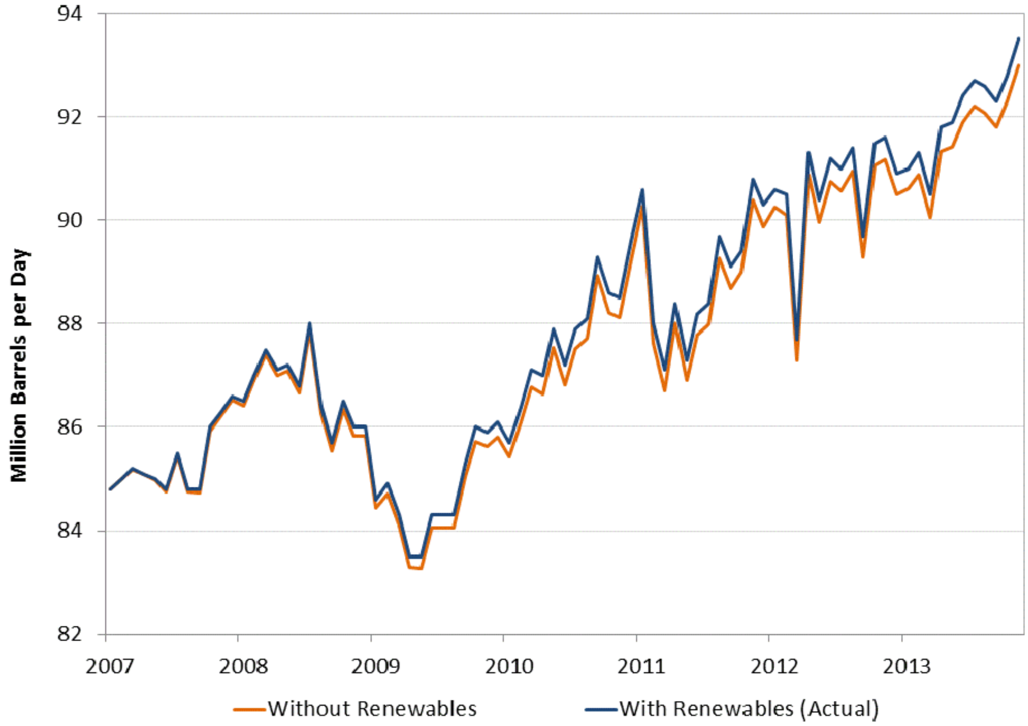
The renewable fuel program's effect can be seen from Figure 4 and Figure 5. According to the U.S. Department of Energy, the amount of ethanol blended into the petroleum stream increased dramatically after passage of the Energy Independence and Security Act of 2007 (EISA) as shown on Figure 4. The "without" supply volume shown in Figure 5 was calculated assuming Congress did not enact the renewable fuels mandate and the availability of renewable fuels did not increase from pre-2007 levels. Figure 5 shows the amount of oil supplied to the world monthly from 2007 through 2013. Also shown in Figure 5 is the lower volume that would have been observed had the renewable fuels program not been enacted.

Figure 4: Ethanol Blended into U.S. Petroleum Markets After 2007 Passage of EISA, 2007–2013



Source: US EIA

Figure 5: Global Monthly Crude Oil Supply
With and Without U.S. Renewable Fuels Program, Jan 2007 to Nov 2013

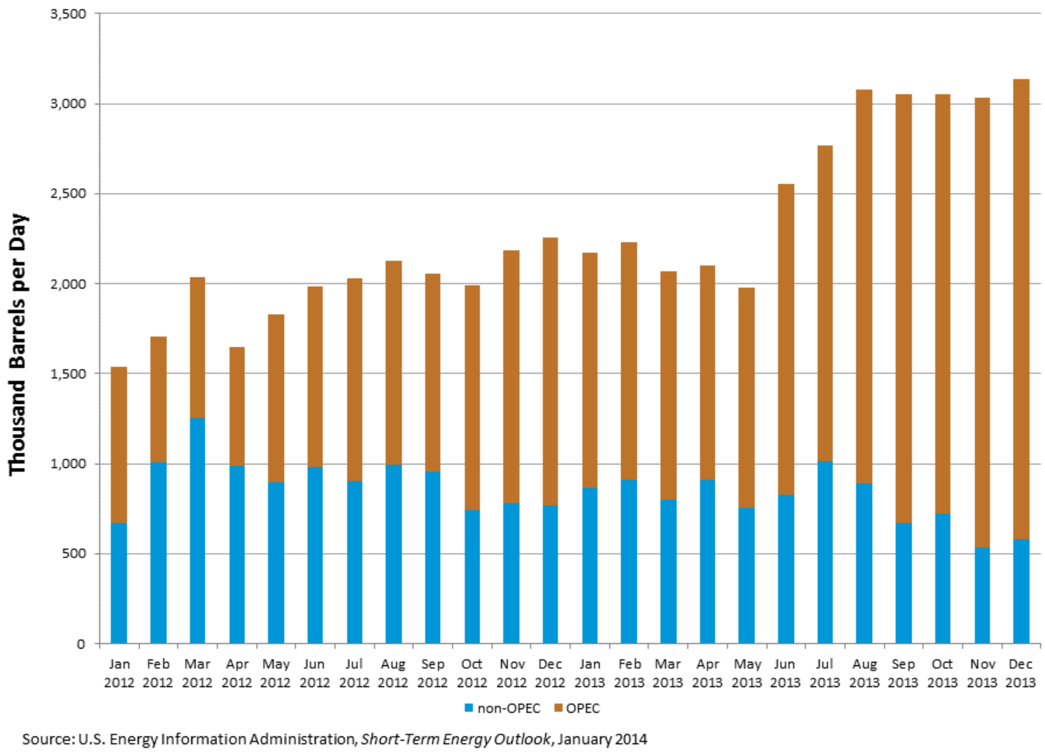


Source: EIG; PKVerleger, LLC

The "what-if" simulations assume that other world hydrocarbon suppliers would not have boosted production to offset the lost supply. One must also assume that consuming governments would not release strategic stocks to moderate any price increase associated with the reduced supply.

The first assumption is almost certainly correct regarding 2013. During the second half of the year, oil supply disruptions happened in a large number of countries, forcing the world's largest exporter, Saudi Arabia, to push output to more than eleven million barrels per day. By August, unplanned production outages in OPEC and non-OPEC countries exceeded 3 million barrels per day, and remained at those levels through December as seen on Figure 6.

Figure 6: Estimated Unplanned OPEC Crude Oil and Non-OPEC Liquid Fuels Production Outages, 2012–2013



Estimating the Impact of U.S. Renewable Fuels on Crude Oil Prices

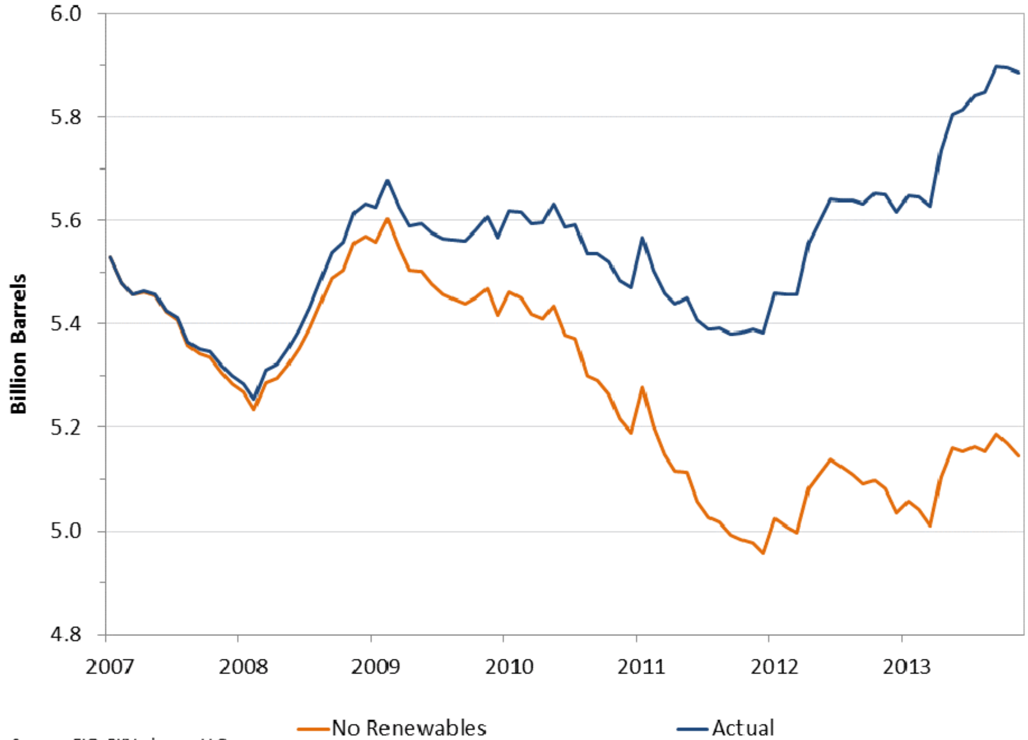
We simulated an alternative price path using the model described above for the "what-if" scenario. The model's price predictions were based on stock changes. In the simulations, we use our "what-if" calculations of global supply to recalculate the inventory level month by month assuming no offsetting change in production or consumption. We discuss this admittedly strong assumption later.

The calculation is based on the identity for end-of-period inventories:

$$\text{Inventories}_t = \text{Inventories}_{t-1} + \text{Supply}_t - \text{Consumption}_t$$

Figure 7 shows global commercial petroleum stocks as initially reported by EIG and under the "what-if" scenario of no renewable fuels beyond the 2007 (pre-EISA) levels. The data on inventory changes under the "what-if" renewable scenario was substituted into the model, and Figure 7 shows the resulting predicted level of commercial crude oil stocks.

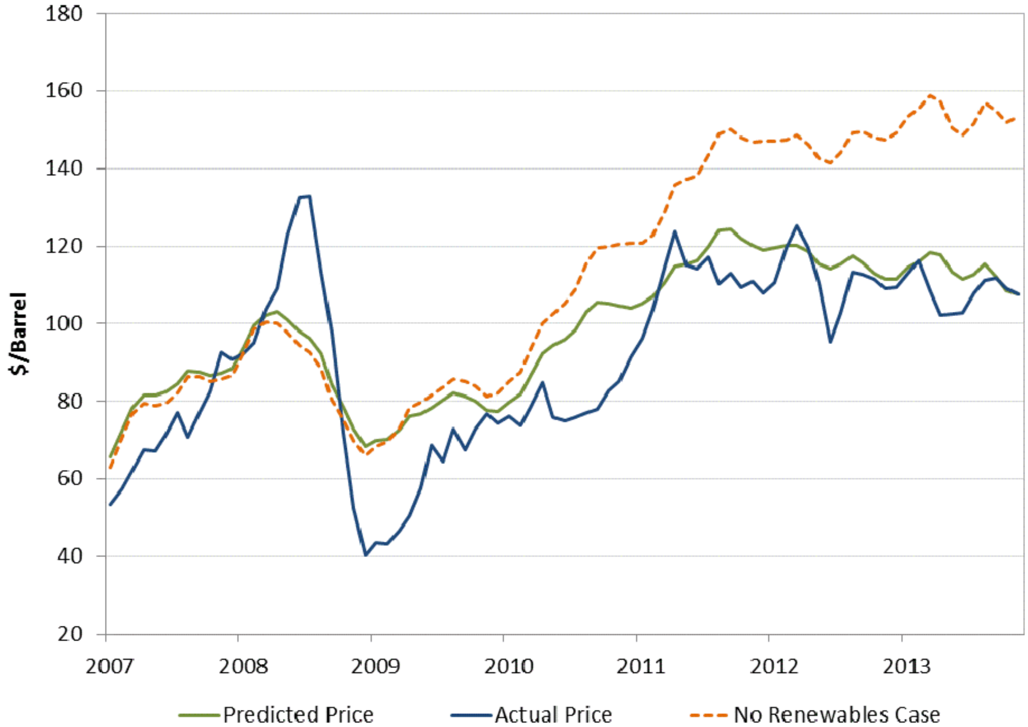
**Figure 7: Actual Global Commercial Crude Stocks vs.
Stocks Excluding Renewables, Jan 2007 to Nov 2013**



Source: EIG; PKVerleger, LLC

Using the estimated relationship between stocks and prices, we then predict (backcast) crude oil price based on historic data and the alternative "what-if" case where U.S. ethanol consumption remains at pre-2007 levels, along with the actual observed DB prices, shown on Figure 8. From Figure 8, we see that the model accurately predicted the November 2013 price of about $108 per barrel. Had the renewable fuels program not been in effect, however, the model predicts a price level of $153. This implies a current crude oil price benefit from all ethanol volumes blended into U.S. fuels is about $45 per barrel, or about $1 per gallon at the pump.

Figure 8: Actual Dated Brent Prices vs. Predicted Brent Price for Base Case and No Renewable Scenarios, Jan 2007 to Nov 2013



Source: PKVerleger, LLC.

A Note on Market Adjustment

The conclusions regarding the overall and cumulative benefit of the renewable fuels program depend on any global supply response under the "what-if" scenario. The divergence in the predicted price under the base case compared to the prices simulated in the "what-if" case for the renewable fuels program begins in 2009 and grows steadily. Whether this would have occurred or whether one or two OPEC members would have boosted production to take advantage of higher prices obviously cannot be known.

Having watched markets for years, though, we suspect the renewable fuels program would have begun to dampen the crude price rise no later than January 2011, when Libyan crude collapsed. That event caused DB prices to rise from $91 per barrel in December 2011 to $123 in April 2012. During the period, Saudi Arabia and a few other producers scrambled to boost output and attempted to blend crudes to produce a synthetic oil that could be processed by refiners relying on Libyan crude. These producers were only partially successful. In June 2012, consuming countries also attempted to alleviate the shortage by releasing strategic stocks. They were even less successful.

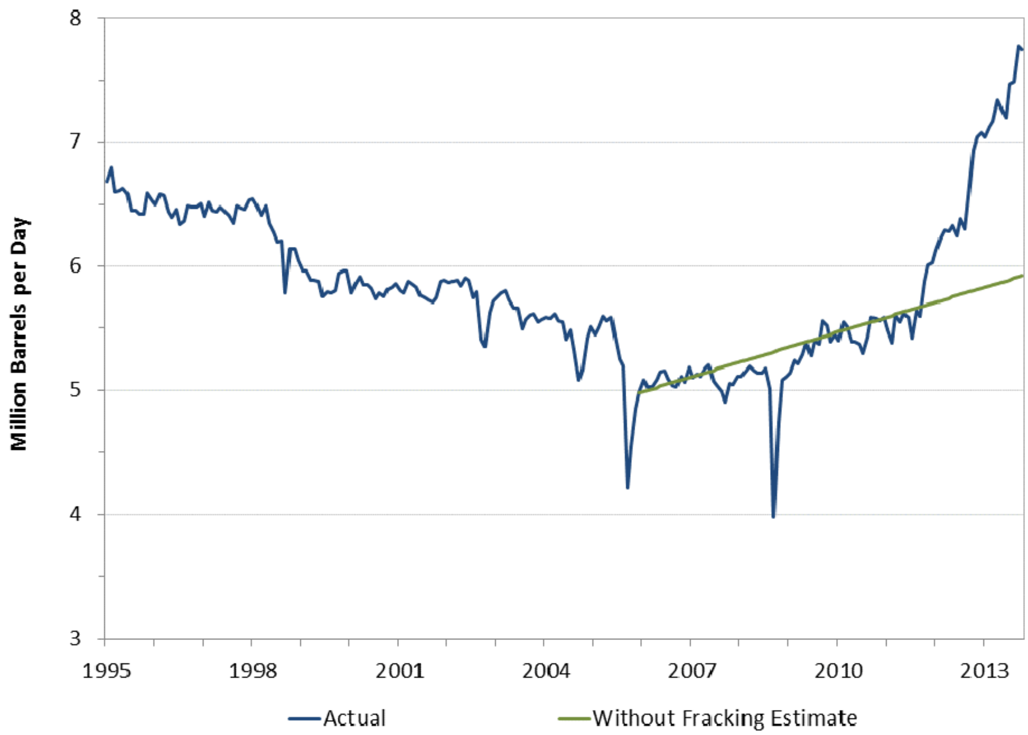
By mid-2011, DOE statistics show that ethanol volumes blended into crude were approximately 850,000 barrels per day, roughly double the volume before EISA passed. The incremental 400,000 barrels per day of ethanol helped moderate the global crude price rise. Assuming the renewable fuels program only began to affect crude prices in 2011, one finds it trimmed crude prices by $25 per barrel in 2013, or about $0.60 per gallon.

The RFS program certainly paid benefits in 2013. As noted above, 2013 saw several prolonged global crude supply disruptions. During the year, blenders introduced roughly 950,000 barrels per day into U.S. fuel supplies, an increase of 500,000 barrels per day from the level observed prior to the RFS program. To impose the strong assumption that the program had no impact prior to 2013, we can calculate the price impact of commercial stock changes based on ethanol volumes (in excess of the pre-2007 levels) introduced only during 2013. Even if we make this excessively conservative assumption, we still conclude that this incremental supply would have lowered prices by roughly $10 per barrel by the end of 2013, or about $0.25 per gallon.

Comparing Expanded Renewables to the Fracking Revolution in the U.S.

The overall contribution of renewable fuel to reducing crude oil prices is about the same as the current impact of fracking in the U.S. We performed the same type of calculation to study the impact of fracking. As Figure 9 shows, U.S. crude oil output has increased very sharply, particularly since the end of 2011. For the "what-if" without fracking case, we assumed U.S. production continued along the trend observed from 2006 to 2011.

Figure 9: Actual U.S. Monthly Crude Oil Production vs. Levels Without Fracking, 1995–2013



Source: US EIA; PKVerleger, LLC

Figure 10 presents the oil supply volume that would have been available to the world had the fracking revolution in the U.S. not taken place. The divergence is especially pronounced during 2012 and 2013, and by the end of 2013, available world supply would have been reduced by 1.9 million barrels per day absent the significant contribution that U.S. fracking had on global supply.

Figure 10: Global Monthly Crude Oil Supply
With and Without U.S. Fracking, Jan 2007 to Nov 2013

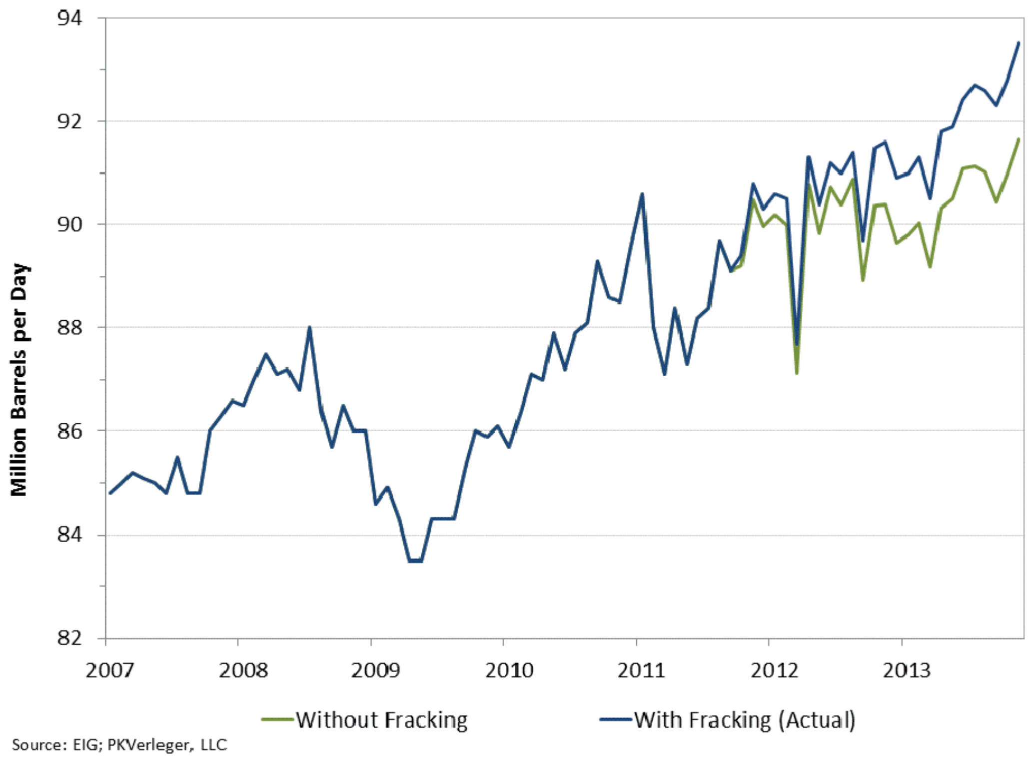
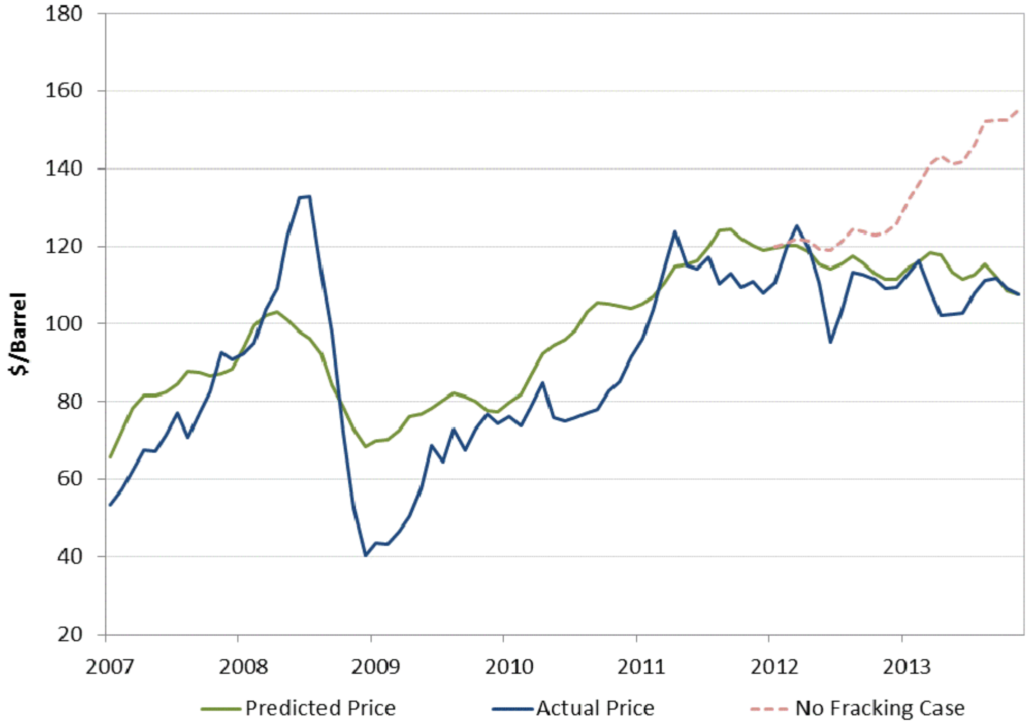


Figure 11 shows the impact of the additional supply from U.S. fracking on crude oil price, which would have increased to about $155 without the U.S. fracking contribution to oil stocks. This impact is nearly identical to the crude oil price benefit estimated from the renewable fuels program. When we combine the two cases – removing the contribution of both the renewable fuel program and U.S. fracking supply, we find that the world crude oil prices would have reached $205 per barrel by the end of 2013, nearly double the observed price. This shows the benefit of pursuing an "all of the above" fuels strategy of cutting demand through the substitution of renewables and boosting supply using new technology.

Figure 11: Actual Dated Brent Prices vs. Predicted Brent Price for Base Case and No US Fracking Scenarios, Jan 2007 to Nov 2013



Source: PKVerleger, LLC

Conclusion: Renewable Fuels Benefit Consumers by Lowering Crude Oil Prices

By using a model that predicts the movement of Dated Brent prices based on changes in global commercial stocks, we assess the effect of the U.S. renewable fuels program. We show that renewable fuel has made a significant contribution to lowering crude prices, both overall and at the margin through recent expansion of the RFS mandate.

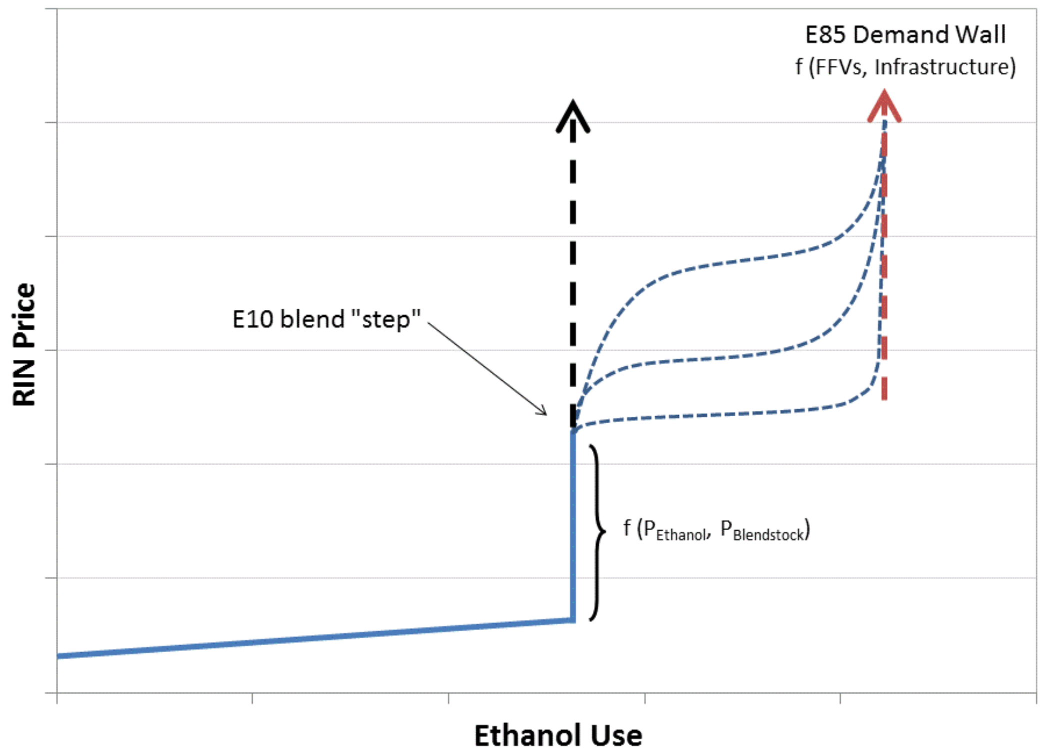
The RFS program provides an important diversification benefit to U.S. energy supply—when global crude markets tighten, then mandates of the RFS program become more valuable even as they become more economical to meet (as we demonstrate in the next section). Thus, the policy acts like a hedge to oil prices, or if one prefers, an insurance policy. An expanding renewable fuels mandate would reduce OPEC leverage in global oil markets, at a time when physical supplies are constrained and OPEC influence is high. These benefits should not be ignored when considering the level of the renewable obligation.

II. OVERCOMING THE BLEND STEP

In its proposed rule, EPA attempts to estimate how much E85 will be sold without any reference to price of ethanol, gasoline, or RINs. However, the RFS is a market-based program of mandates that requires some meaningful forecast of prices along with quantities. At the heart of the issue is the role of E85 to overcome the "blend wall." We recognize from the outset that the E10 limit for conventional gasoline-fueled vehicles does, in fact, constitute a genuine constraint on ethanol volumes *into conventional vehicles*. But there is a fleet of nearly 15 million flex-fuel vehicles (FFVs) that do not face such a constraint and about 2,670 stations that offer E85, primarily in the Midwest.

Between zero and 10% (E10) the wholesale market for ethanol is quite straightforward: when ethanol prices are below gasoline blendstock prices on a $/gallon (volumetric) basis, there is a cost-based incentive to blend up to the 10% limit that applies to conventional retail gasoline. This incentive does not require high RIN prices, and likely was a primary factor in expanding ethanol volumes in the early years of the RFS program. Without any other pathways for expanded ethanol consumption, 10% would indeed be a "blend wall"—RIN prices would soar without any additional ethanol being consumed. But there are other options for ethanol use, which higher RIN prices can stimulate. In fact, the blend wall is really a blend *step*, with the height of the step being a function of the relative prices of E85 and E10 that stimulate additional E85 sales. What's really at issue here is (1) how high is the blend step? and (2) how do consumer fuel choices affect the slope of the RIN supply curve beyond 10%? These basic questions are depicted graphically in Figure 12 below, showing different possibilities for the slope and shape of the E85 blend step (along with the limit of E85 use due to the size of the FFV fleet and available fueling infrastructure).

Figure 12: The Blend Step and E85 Demand

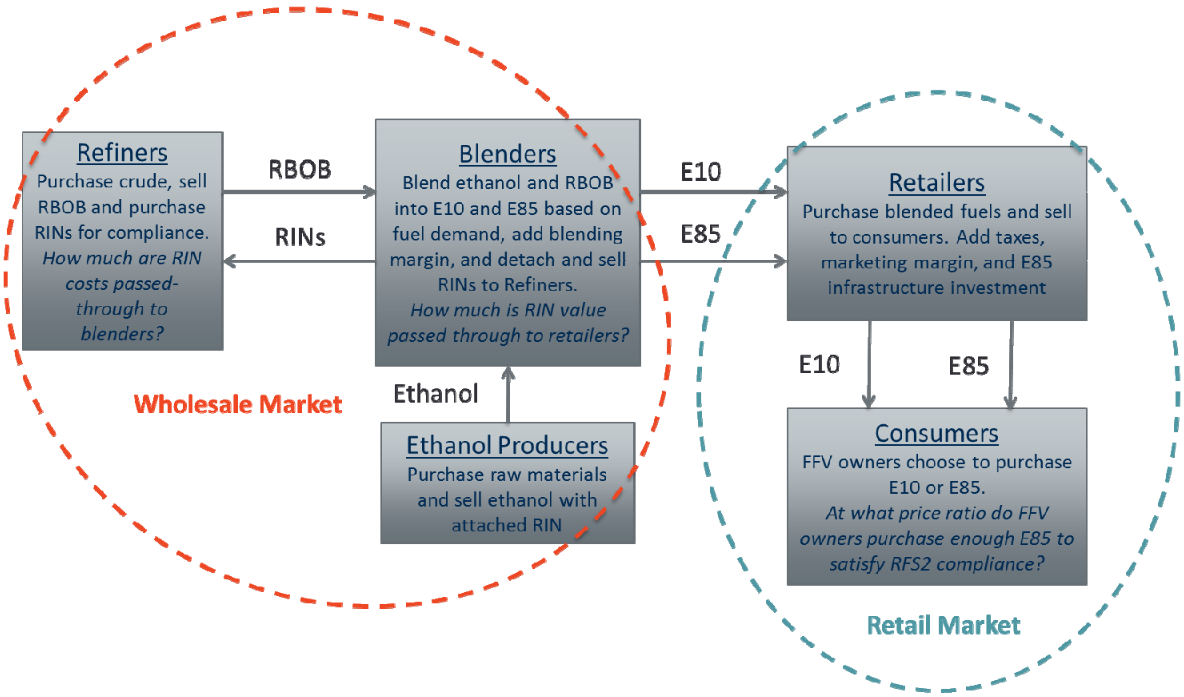


Meeting future RFS goals and overcoming the E10 blend wall (*i.e.*, taking the E85 blend step), will require additional E85 sales. While E85 sales have been growing over the past several years as the number of stations selling E85 has increased, access to E85 stations alone as outlined in the EPA proposed rulemaking will only lead to so much growth in E85 market share. Reaching the levels necessary to meet the goals of the RFS will require a steady price signal from the RIN market to incentivize lower E85 prices at the pump. The analysis described below considers the relationship between renewable volume obligation (RVO) levels, RIN prices, retail prices of E10 and E85, and E85 sales.

Modeling the Blend Step for E85

It is necessary to model the structure of the RIN market and fuel supply chains to understand how additional RINs are generated and how RIN prices flow through to the pump. RINs exist in the wholesale motor gasoline fuel market—generated by ethanol producers, detached and sold by blenders, and obtained by obligated parties (*e.g.*, refiners, many of whom are integrated into blending and marketing). Up until recently, consumers have largely remained shielded from this market as RFS obligations have been met by increasing the amount of ethanol blended into regular gasoline and RIN prices were negligible. Overcoming the E85 blend step requires additional ethanol usage and RIN generation through increased E85 sales. For this reason, the link between RIN prices and retail fuel prices begins to play a more important role in meeting the RFS mandates. For the value of RINs to impact E10 and E85 prices at the pump, RIN prices must flow through the supply chain (see Figure 13) from the wholesale market for the ethanol and gasoline blending stocks to the retail gas pump for more drivers of FFVs to choose E85 over E10 at the pump.

Figure 13: RIN Supply Chain Analysis Framework



Due to the interaction between the wholesale market for blendstocks and retail purchases of fuel, projecting RIN values requires more than evaluating wholesale ethanol and gasoline-blendstock prices alone. Additional factors need to be considered along the supply chain from the refiners to the consumers, including the degree to which refiners and blenders pass-through the cost and benefits of RFS compliance, changes in profit margins, the cost of additional equipment to transport, store, and sell E85, and how consumers' purchasing decisions change when E85 price vary.

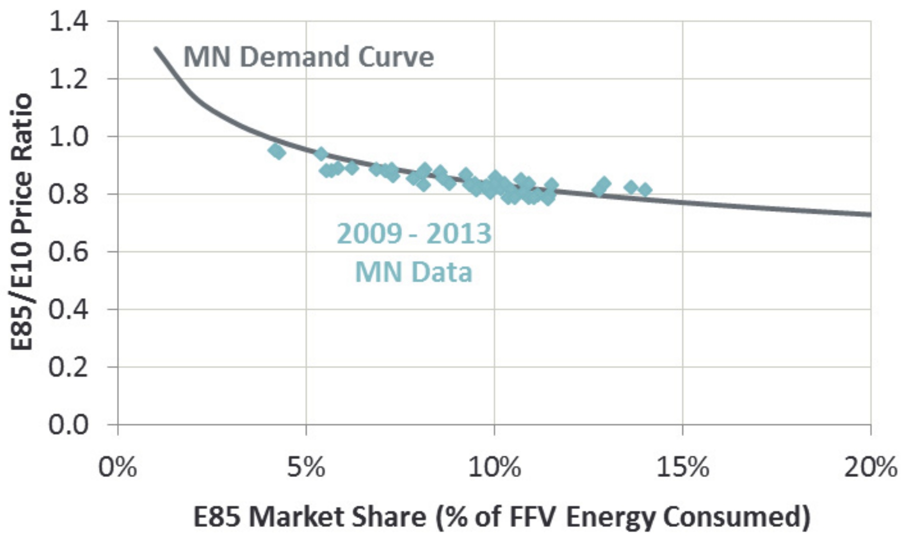
In our analysis, we have used market data to explore in more detail two of these factors: the market behavior of consumers' E85 purchases and how refiners or blenders pass on the costs and benefits of RFS compliance costs downstream to retail customers (in the following section). Pulling this information together, we can project the RIN price required to incentivize increasing E85 sales to meet an increasing RFS mandate.

Fuel Choice for FFV Owners

First, we will look at how consumers respond to differences in price between regular unleaded gasoline (E10) and E85. The main question is "do changes in E85 prices relative to E10 prices impact FFV fuel purchases?" Our statistical analysis of consumer behavior in Minnesota, where there exists a suitably comprehensive historic dataset, shows the answer to this question is a resounding "yes." The analysis of Minnesota E85 price and sales volume data is described in Appendix A.

In order to characterize FFV owner fuel choices, we used the Minnesota data on monthly fuel sales and prices from 2009–2013 and ran regressions that take into account the ratio of E85 and E10 prices, the fuel consumption of FFVs in Minnesota and seasonal factors to create an E85 demand curve for FFV owners, as shown in Figure 14. E85 prices over that time frame have ranged from 78–95% of E10 prices and the FFV owners have responded accordingly by purchasing more E85 fuel when the prices are lower.

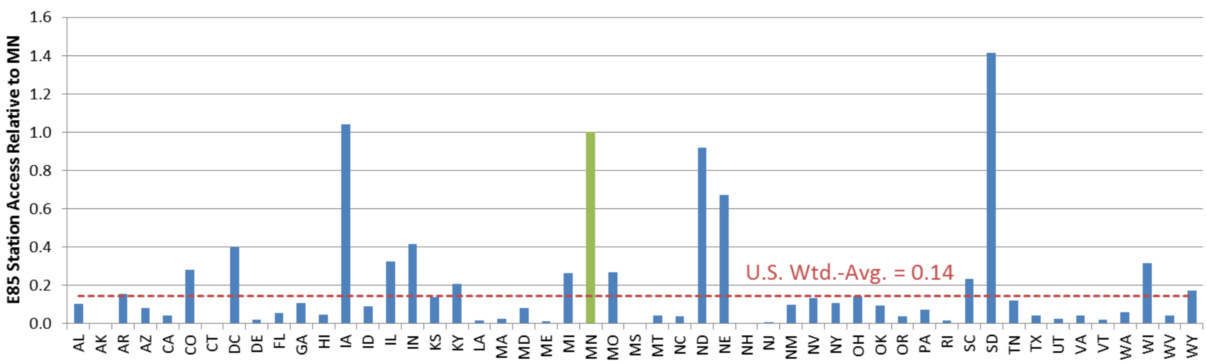
Figure 14: Minnesota E85 Demand Curve



E85 sales are expected to be highest in the Midwest states where the majority of corn-based ethanol is produced, the relative price of ethanol to gasoline tends to be lower, and where we find the highest concentration of E85 stations. Six Midwest states (Iowa, Indiana, Illinois, Michigan, Minnesota, and Wisconsin) contain 45% of all the E85 stations across the U.S. Minnesota has the most E85 stations (337) with Iowa having the second most (194).[2]

What do the Minnesota results tell us about potential E85 purchases across the U.S.? E85 station access is generally considered to be the limiting factor to increasing E85 sales (in addition to fuel prices, of course).[3] We therefore calculate a proxy variable to measure consumer access to E85 stations. The proxy variable is calculated by dividing the number of E85 stations in each state by the total motor gasoline fuel consumed in the state and comparing those figures to the value observed in Minnesota. Using this variable, two states have higher levels of access (Iowa and South Dakota) and the country overall has a weighted average of E85 access of 0.14 relative to Minnesota, as shown in Figure 15.

Figure 15: E85 Station Access in US States Relative to Minnesota



If we were to assume that E85 demand by FFVs is proportional to the number of stations per fuel demand, we could apply a scaling factor of 0.14 to the Minnesota demand curve shown in Figure 14 to estimate U.S. E85 demand. In other words, we could assume that at each E85/E10 price ratio, E85 purchases in the U.S. would be proportional to predicted Minnesota sales based on applying the 0.14 scaling parameter as representing "effective" access to E85. However, there may be additional factors influencing E85 demand such as public awareness of E85, FFV owner awareness of vehicle capability and critical mass of E85 marketing suggesting a less than proportional response from FFV owners outside of the Midwest. Accordingly, we have chosen to apply a much more conservative scaling factor of 0.10 to our estimate of U.S. E85 demand based on the Minnesota data, as shown in Figure 16. Using a value of 0.10 for this scaling factor allows

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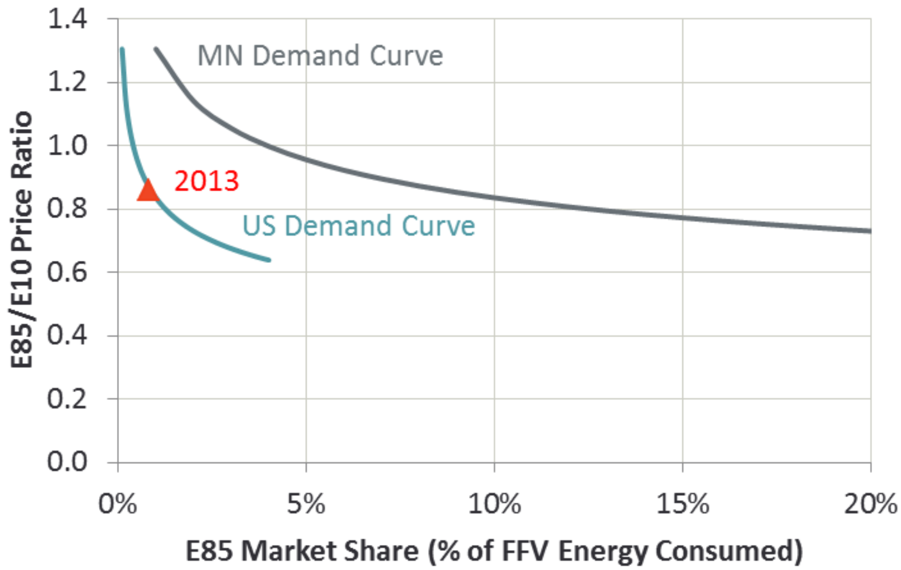
2 Data from DOE Alternative Fuels Data Center (as of January 9, 2014) totaled 2,669 stations offering E85 in the U.S., both public and private, see http://www.afdc.energy.gov/fuels/stations_counts.html. There are nearly 2,400 public stations.

3 Babcock, B.A., and S. Pouliot, 2013, "Impact of Sales Constraints and Entry on E85 Demand," Policy Briefing Paper 13-PB 12. Center for Agricultural and Rural Development.

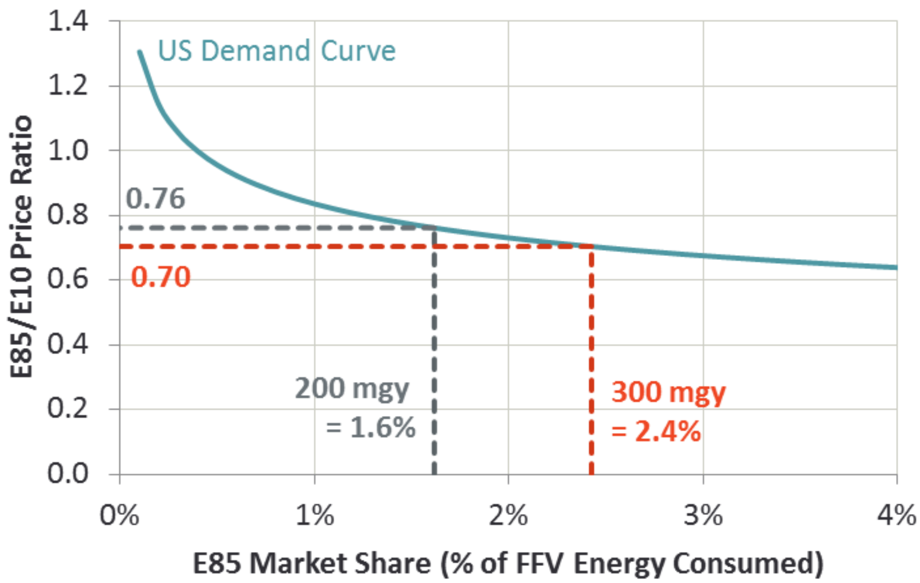
us to calibrate the U.S. demand curve to data available for U.S. 2013 E85 sales when the average ratio of retail E85 to E10 prices was 0.86 and U.S. FFV E85 demand was roughly 0.8% of energy consumed.

Figure 16: US E85 Demand Curve



Our analysis shows that increased E85 sales in 2014 can occur if the E85 price is reduced through the RIN pricing mechanism. Based on the estimated U.S. demand curve, 200 million gallons of E85 (1.6% of FFV fuel demand) would be sold if the E85 price is reduced to 76% of E10 and 300 million gallons (2.4% of FFV fuel demand) would be sold if the E85 price drops further to 69% of E10 prices. This relationship is shown in Figure 17.

Figure 17: Price Ratio to Incentivize Increased E85 Sales in 2014



E85 Sales and RIN Prices

Applying this understanding of consumer behavior to the RIN supply chain analysis framework described above in Figure 13, we are able to project the RIN prices required to incentivize increased E85 sales in order to reach higher RVO levels under the RFS. Later we discuss assumptions about RIN cost pass-through, but at this point we will assume that 100% of RIN costs are passed-through from refiners to blenders, and that blenders pass through 100% of the value of RINs down to retail consumers. That is, we assume constant margins throughout the chain of transactions. Maintaining constant margins provides the impetus for RIN-related discount of E85 prices necessary to achieve the level of E85 sales to meet the mandate. Additional details on the modeling framework and key assumptions are given in Appendix B.

Given the U.S. demand curve for E85 and the projected costs of RBOB and ethanol in 2014, we find that E85 sales can be incentivized by increasing RIN prices as shown in Figure 18.[4] An RFS mandate that requires 200 million gallons per year (mgy) of E85 sales would be expected to result in a RIN price of $0.34 and for 600 mgy, $0.99.

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4 RBOB ($2.676/gallon) and ethanol ($1.723/gallon) prices have been calculated based on the average 2014 futures prices (February through December) as of January 21, 2014. Source: http://www.cmegroup.com

Figure 18: E85 Sales and RIN Prices

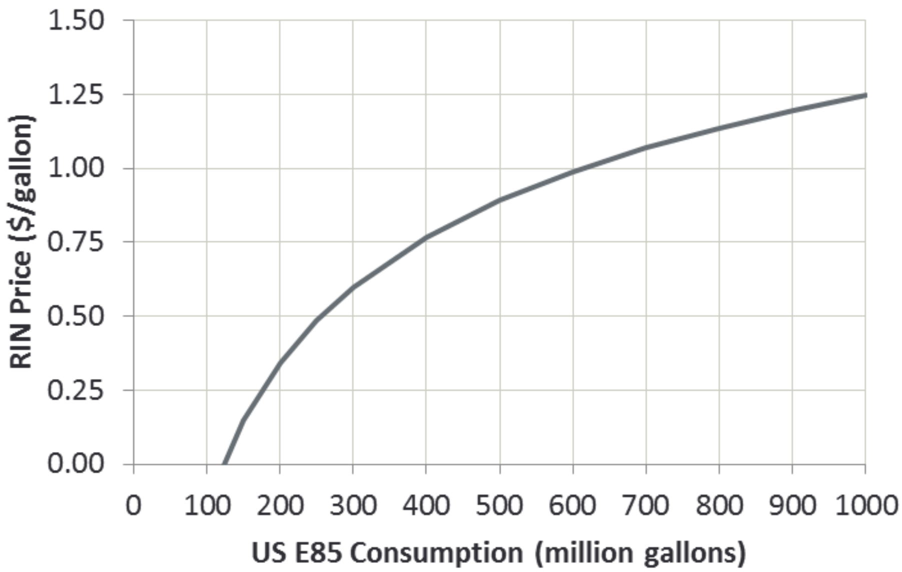


Table 2: E85 Sales and RIN Prices

E85 Sales *Million Gallons*	**RIN Price** *$/gallon*
200	0.34
300	0.60
400	0.77
500	0.89
600	0.99
700	1.07
800	1.14
900	1.20
1000	1.25

Table 3 shows how higher RIN prices work their way through the supply chain to incentivize increasing volumes of E85 sales. The price of gasoline blendstock (RBOB) sold to the blender will increase by 10¢ going from 200 to 1,000 million gallons of E85. However, the increase in RBOB prices is offset by the lower effective price of the blended ethanol, which is reduced by 89¢ with the same increase in E85 sales. This results in an increase in E10 prices of less than 1¢. At the same time, E85 prices plunge over this range from $2.40/gallon to $1.75/gallon, reflecting the increased RIN-induced discount relative to E10 required for motorists to purchase the higher quantities of E85.

Table 3: RIN, Blendstock and Fuel Prices for Increasing E85 Sales

		E85 Sales (million gallons)		
Component	**Units**	**200**	**600**	**1,000**
RFS2 Mandate				
RFS2 RVO	%	9.2%	9.4%	9.6%
Ethanol in Gasoline	%	9.9%	10.1%	10.3%
RIN Price	**$/gal**	**0.34**	**0.99**	**1.25**
Refiner				
RBOB Price	$/gal	2.68	2.68	2.68
RIN Cost Passed on to Blender	$/gal	0.04	0.11	0.14
Price Charged to Blender	**$/gal**	**2.71**	**2.79**	**2.82**
Blender/Marketer				
Ethanol Price	$/gal	1.72	1.72	1.72
Blender RIN Value Pass-Through	%	100%	100%	100%
RIN Value Passed on to Retailer	$/gal	-0.34	-0.99	-1.25
Effective Price of Ethanol	**$/gal**	**1.38**	**0.73**	**0.48**
Wholesale E10	$/gal	2.58	2.58	2.58
Wholesale E85	$/gal	1.73	1.27	1.09
Retailer				
Retail E10	**$/gal**	**3.16**	**3.16**	**3.16**
Retail E85	**$/gal**	**2.41**	**1.95**	**1.77**
E85/E10 Price Ratio at the Pump		0.76	0.62	0.56
Impact of RINs on E10 Price	$/gal	0.000	0.001	0.002

Gasoline Blendstock and Ethanol Prices: Effect on RIN Price

We have made several assumptions throughout this analysis that are worth exploring further, including the wholesale prices for RBOB and ethanol, E85 station access, and blender pass-through of RIN value. In Table 4, we evaluate the relationships between gasoline blendstock prices, ethanol prices, RIN and retail fuel prices.

Table 4: Sensitivities of RIN Price to Gasoline Blendstock and Ethanol Prices (600 million gallon E85 Case)

Component	Units	Base Prices	RBOB Price -20%	RBOB Price + 20%	Ethanol Price -20%	Ethanol Price + 20%
E85 Sales	million gallons	600	600	600	600	600
RIN Price	**$/gal**	**0.99**	**1.21**	**0.77**	**0.66**	**1.32**
Refiner						
RBOB Price	$/gal	2.68	2.14	3.21	2.68	2.68
RIN Cost Passed on to Blender	$/gal	0.11	0.14	0.09	0.07	0.15
Price Charged to Blender	**$/gal**	**2.79**	**2.28**	**3.30**	**2.75**	**2.82**
Blender/Marketer						
Ethanol Price	$/gal	1.72	1.72	1.72	1.38	2.07
Blender RIN Value Pass-Through	%	100%	100%	100%	100%	100%
RIN Value Passed on to Retailer	$/gal	-0.99	-1.21	-0.77	-0.66	-1.32
Effective Price of Ethanol	**$/gal**	**0.73**	**0.51**	**0.96**	**0.72**	**0.75**
Wholesale E10	$/gal	2.58	2.10	3.06	2.55	2.62
Wholesale E85	$/gal	1.27	0.97	1.56	1.25	1.29
Retailer						
Retail E10	**$/gal**	**3.16**	**2.68**	**3.64**	**3.13**	**3.20**
Retail E85	**$/gal**	**1.95**	**1.65**	**2.24**	**1.93**	**1.97**
E85/E10 Price Ratio at the Pump		0.62	0.62	0.62	0.62	0.62
Impact of RINs on E10 Price	$/gal	0.001	0.002	0.001	0.001	0.002

It is important to note that higher RIN prices alone do not necessarily imply that E10 gasoline prices will be higher. In fact we find that E10 prices with and without the RFS are approximately equal under our assumptions regarding price competition. Also, the RIN market will partially dampen the impact of RBOB prices on E10 fuel prices. For example, a lower RBOB price will increase the price of a RIN (by 22¢ for a 20% change oil prices) but will also lower the retail price of E10. In this way, RBOB and RIN prices are mostly offsetting: as gas prices go up, RIN prices go down and vice versa. The RFS program, therefore, provides a natural hedge for crude oil prices changes, insofar as the increased value of ethanol as a result of higher oil prices is reflected in lower RIN prices necessary to induce E85 sales to maintain any particular mandate level.

As would be expected, lower ethanol prices will reduce RIN prices and retail E10 prices. However, the E10 price impact is relatively minor compared to the changes seen with different RBOB price assumptions.

If, as we are currently assuming, that RIN costs of refiners are passed on to consumers, you would expect significant RIN prices as we are seeing in Table 4 to have an impact on regular gasoline purchased by non-FFV drivers. However, the RIN prices in this case show a minimal impact on regular unleaded gasoline (E10) as the higher cost of the RBOB will be largely offset by the lower effective cost of blending ethanol, a benefit that is assumed to flow to consumers under the assumption of constant blender margins.

Expanded E85 Marketing and Infrastructure: Effect on RIN Prices

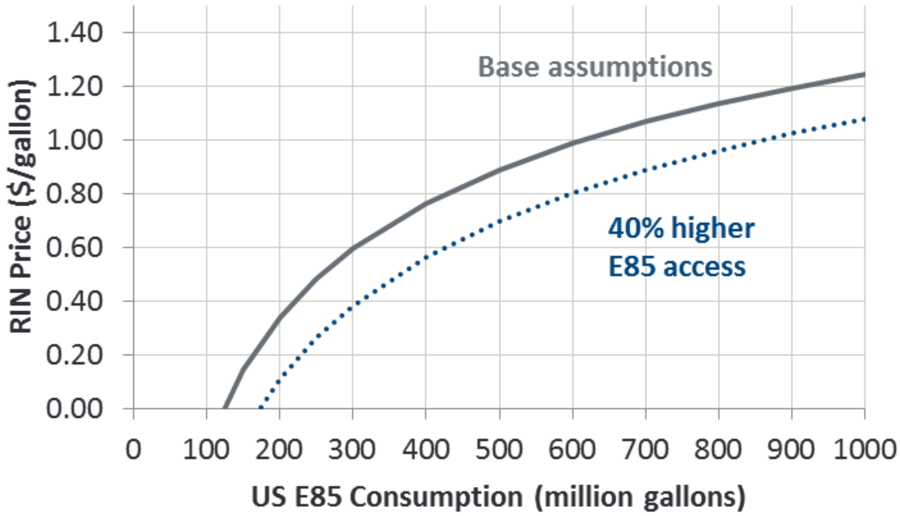
As described above, we scaled the Minnesota E85 demand curve to the U.S. using a conservative factor that assumes that consumer access to (or awareness of) E85 fueling stations was lower in other states than implied by the simple ratio of E85 stations to overall fuel demand. Although that is an appropriately conservative assumption to describe the market today, we would expect that a higher mandate would give retailers additional incentive to market existing E85 stations more effectively and make investments to expand access. Accordingly, we would expect that effective E85 fuel access would increase. Table 5 shows the impact of assuming 20% and 40% more effective access (the latter reflecting effective E85 access proportional to the Minnesota level).

Table 5: Sensitivities of RIN Prices to E85 Access Assumptions (600 million gallon E85 Case)

Component	Units	Base Access	E85 Access + 20%	E85 Access + 40%
E85 Sales	million gallons	600	600	600
E85 Access Relative to MN		0.10	0.12	0.14
RIN Price	**$/gal**	**0.99**	**0.89**	**0.80**
Refiner				
RBOB Price	$/gal	2.68	2.68	2.68
RIN Cost Passed on to Blender	$/gal	0.11	0.10	0.09
Price Charged to Blender	**$/gal**	**2.79**	**2.78**	**2.77**
Blender/Marketer				
Ethanol Price	$/gal	1.72	1.72	1.72
Blender RIN Value Pass-Through	%	100%	100%	100%
RIN Value Passed on to Retailer	$/gal	-0.99	-0.89	-0.80
Effective Price of Ethanol	**$/gal**	**0.73**	**0.83**	**0.92**
Wholesale E10	$/gal	2.58	2.58	2.58
Wholesale E85	$/gal	1.27	1.34	1.40
Retailer				
Retail E10	**$/gal**	**3.16**	**3.16**	**3.16**
Retail E85	**$/gal**	**1.95**	**2.02**	**2.08**
E85/E10 Price Ratio at the Pump		0.62	0.64	0.66
Impact of RINs on E10 Price	$/gal	0.001	0.001	0.001

As would be expected, increasing access through enhanced consumer awareness of existing facilities and additional E85 stations will lead to more E85 sales at the same E85/E10 price ratio since FFV drivers will be more likely to find a station with an E85 pump for refilling their tank. Improving E85 station access by 40% will lower RIN prices by 19¢. This suggests the prospects for a virtuous cycle of additional E85 sales through greater utilization of current infrastructure that provide incentives for expanded infrastructure.

Figure 19: Impact of E85 Access on RIN Prices



III. EFFECT OF RIN PRICES ON RETAIL GASOLINE PRICES

There has been a fair amount of speculation but little credible analysis that examines the role of RIN prices on retail gasoline prices. One reason that it is difficult to isolate the impact of RIN prices on retail gasoline prices is the inherent complexity of the motor fuel supply industry, with multiple pricing points through a complex chain of commerce. Another reason is the structure of the RFS, which places obligations at the refinery level, but has RINs separated at the blending level. Refiners and blenders are not all similarly situated—many refiners are integrated or affiliated with blenders to varying degrees, while some are independent. Regional factors play a significant role as well, with current opportunities to sell additional volumes of E85 concentrated in the Midwest. Finally, retail gasoline prices are perennially the subject of debate, particularly when they begin to rise.

The politicization of this issue has brought forth some (to put it politely) inconsistent positions. Renewable fuel advocates, who routinely portray the oil industry as rapacious gougers of consumer wallets, sponsor studies that contend that oil companies meekly forgo the opportunity to pass on the cost of RINs, so that the costs of the renewable fuel program disappear long before prices are set at the pump. Meanwhile, the oil industry abandons its usual posture of public spirited enterprise at the mercy of powerful market forces and warns ominously that setting any RVO beyond the blendwall will leave the industry no choice but to withhold domestic gasoline sales, dramatically raise gasoline prices and induce a severe economic recession.

There are a few areas of widespread agreement that help define the conceptual landscape:

- RINs are "created" when ethanol is produced and sold. The market value of the RIN is latent while the RIN remains "attached" to the gallon of ethanol. The RIN has independent market value after it is "separated" from the ethanol when blended into finished fuel (E10 or E85). There is a secondary market for RINs that establishes its actual market value at any given moment in time. RINs can be held (they expire at the end of the following calendar year), sold in the secondary market, and used by obligated parties to comply with their renewable volume obligation (RVO).

- Most RINs do not actually trade but are used by obligated parties. RINs are "free" to most obligated parties (refiners) who either blend in an integrated operation, an affiliated operation, or when they receive RINs without consideration under contracts with downstream blenders. While "free" in the cash accounting sense, they do have a market value that is established in the secondary market and therefore have an opportunity cost when used for compliance. Obligated parties without access to sufficient RINs can purchase RINs to comply with their RVO from other refiners, or from unaffiliated and/or merchant blenders, who create separated RINs when they blend ethanol into finished fuel and offer these RINs on the secondary market.

- The retail segment of fuel supply is generally competitive, and to the extent permitted by circumstance, retailers seek out the lowest price for fuels they offer to motorists. Refiners only own a small fraction of retail stations. While many independently owned retailers use a refiner's brand, the relationship between the refiner and the branded station is strictly regulated through the Petroleum Marketing Practices Act (PMPA). An increasing share of gasoline is sold by retailers who do not utilize a refiner's brand.

Until last year, when concern about approaching the "blend wall" created a price spike and subsequent turmoil in the RIN market, current-year RINs usually typically traded below 5¢ per gallon. Their primary purpose was to track and ensure compliance, and provoked little regard about the incidence of their cost or value. Assuming a full pass of RIN costs through to retail prices (but no corresponding pass through of RIN credits), a 5¢ per gallon RIN price could have a maximum impact on retail E10 price of a half-penny per gallon, and the maximum E85 price discount could be 4.25¢ per gallon.

RIN Costs, E10 Pump Prices and Profit Margins

As RIN prices rose sharply in 2013, the role of RINs to incentivize additional ethanol use though E85 sales, as well as their impact on retail E10 prices, commanded new attention. What seems to be less appreciated, however, is that these two affects are related—insofar as different assumptions regarding how RIN prices affect wholesale and retail prices (and refining, blending and retailing margins) can produce vividly different answers to the question of how RIN prices might effectively incentivize E85 sales, as well as the level of RIN prices necessary to maintain compliance with RVOs above the so-called "blend wall." Examining this issue empirically is further complicated by the likelihood that price dynamics in the oil industry may be different during periods of reaction and adjustment to new and uncertain market conditions (such as RIN price spikes) compared to periods of relative certainty and more stable expectations. Thus, looking back at 2013 provides only an imperfect indication of industry behavior and pricing that might prevail if RVO levels were more certain and RIN prices conveyed more reliable information.

The model of E85 demand and RIN price explored in the previous section assumed a high degree of price competition throughout the fuel supply industry. This assumption was enforced by imposing the constraint of constant margins in refining, blending and retail sales in all cases examined. Thus, refiners embedded the cost of complying with the mandate (RVO times RIN price) into gasoline blendstock prices, which maintained constant margins at the refinery level. We further assumed that blenders would pass on the value of RINs to retail customers in both E10 and E85 prices, which led to deep discounts for E85 (and negligible net price impacts on E10). This is equivalent (in the accounting sense) to the statement that blenders do not pass on the cost of RINs (as already embedded in blendstock prices), that is, they do not retain the value of the RINs obtained by blending ethanol in the form of higher blending margins.[5] These outcomes were consistent with competitive markets, where horizontal competition (*i.e.*, among firms within a segment) for downstream customers drives out excess profits. It is the model that the oil industry touts as describing their own behavior. The model results also indicate that the RFS program is well designed to induce ethanol sales above the blend step without impairing the profit margins of the fuel supply industry (although it does, by design, reduce volumes of petroleum fuel sold in the U.S.).

Thus, the issue of whether RIN prices "show up at the pump" for consumers of regular (E10) gasoline is not related to the design of the RFS or the implementation of any particular RVO mandate level. It is, instead, an issue of industry profits and pricing behavior. If RIN prices pass through to retail E10 prices, then upstream entities are profiting beyond their normal margins. For instance, when blendstock prices reflect the RIN value of meeting the RVO, and retail E10 prices are also elevated by a commensurate amount, then the blending segment is not passing on to retailers the value of RINs that they generate.

RIN Prices and Retail E10 Prices in 2013

While a complete analysis of local and regional fuel markets to determine if refining and/or blending margins rose with RIN prices is beyond the scope of this study, we do find some evidence that the retail price of E10 was affected by RIN prices in 2013. For example, refining margins reflected RIN prices when we examined Brent Crude and New York Harbor RBOB, after we took seasonal factors into account. This effect was close to the implied RVO level, was statistically significant and was consistent with observations in the product export markets as well as conversations with traders and other industry participants. Therefore, although many refiner obligated parties do not purchase RINs but rather receive them from affiliated blenders,

5 In the model results shown earlier, this was depicted as a lower effective cost of ethanol at the blending stage, an input cost reduction that was passed on to retail customers of E10 and E85.

we model the sector as a whole as imputing their renewable obligation into the blendstock price and examine blending margins.[6]

We also found evidence that the impact of RIN prices was not subsequently "removed" in the blending segment (*e.g.*, the value of RINs was not netted out of the price of E10) in several regional markets, such as New York, Houston, Chicago and Los Angeles. To examine this, we regressed the change in daily retail prices on lagged changes in E10 spot prices, which were computed using the price of the RBOB and ethanol, weighted by 90% and 10%, respectively (with a RIN cost assumed to be imputed into RBOB price) and independently the change in the lagged spot price of RINs (computed as the price of the RIN times the renewable percentage required by the RFS). If the RIN value flowed to consumers, the coefficient would be significant and around -1.0. If blenders retained the RIN value, the coefficient would be zero and/or statistically insignificant. We found the latter in all cases examined.[7]

This suggests that the value of RINs obtained when ethanol is blended into E10, which should flow to retail consumers in a fully competitive market, was retained at the blending level, at least to some extent. In this way, some of the RIN costs (that we assume were imputed into RBOB costs) were passed on through to E10 consumers. While we would not expect such pricing conduct to be sustainable, it does reflect near-term, opportunistic pricing behavior that was not immediately counteracted by competitive pressures from downstream retailers. In other words, while undesirable from a consumer perspective, these outcomes should be transitory. Even if the *entire* costs of RIN obligations were, in fact passed downstream during 2013, they would have added only about 5–6¢ per gallon on E10, a year in which average regular retail gasoline prices varied by about 4.1¢ per gallon on a week-to-week basis.[8]

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6 This assumption reflects the situation of merchant refiners and blenders transacting blendstock and RINs. In the full pass-through case, the blender buys blendstock with the imputed RIN cost, blends ethanol, sells the RINs back to the refiner, and passes on the proceeds of the RIN sale downstream to retailers. If the blender is obligated to give the RINs to the refiner without receiving payment and sells the finished fuel downstream at cost plus ordinary margin, then the refiner margin is instead increased to the extent that blendstock price includes the RIN cost.

7 For example, the New York City regressions were performed on data from January 2010 through August 2013. The change in the lagged (1-day) RIN price variable was estimated at 0.0008 (t-value = 0.6114), with the regression $R^2 = 0.415$.

8 This figure was derived using 2013 EIA average weekly U.S. regular retail gasoline price (all formulations) data, as the average of the absolute values of week-to-week changes.

Effect on RIN Price of Blender Pass-Through Assumptions

Returning to the model discussed in the previous section, we can examine the implications of non-competitive pricing by relaxing the assumption that blender margins are constant. Recall that we previously assumed that 100% of the value of separated RINs would be passed on to consumers, effectively neutralizing the RIN cost on E10 and providing deep discounts for E85 in order to incentivize sales. If we instead assume that only 75% of the RIN value is passed on to consumers, we see that retention of excess blending profit margin can increase RIN prices and impose an additional price burden at the pump, as shown in the Table 6 below.

Table 6: Effect Blender Margins and Pricing on RIN Price (600 million gallon E85 Case)

Component	Units	100% Blender RIN Value Pass-Through	75% Blender RIN Value Pass-Through
E85 Sales	million gallons	600	600
RIN Price	**$/gal**	**0.99**	**1.30**
Refiner			
RBOB Price	$/gal	2.68	2.68
RIN Cost Passed on to Blender	$/gal	0.11	0.15
Price Charged to Blender	**$/gal**	**2.79**	**2.82**
Blender/Marketer			
Ethanol Price	$/gal	1.72	1.72
Blender RIN Value Pass-Through	%	100%	75%
RIN Value Passed on to Retailer	$/gal	-0.99	-0.98
Effective Price of Ethanol	**$/gal**	**0.73**	**0.75**
Wholesale E10	$/gal	2.58	2.61
Wholesale E85	$/gal	1.27	1.29
Retailer			
Retail E10	**$/gal**	**3.16**	**3.19**
Retail E85	**$/gal**	**1.95**	**1.97**
E85/E10 Price Ratio at the Pump		0.62	0.62
Impact of RINs on E10 Price	$/gal	0.001	0.034

This example shows that passing only 75% of the separated RIN value to retail customers will raise the RIN price necessary to attain a level of 600 million gallons of E85 by about $0.31. At the same time, the price of E10 would increase by almost 4¢ a gallon and E85 price would increase by about 2¢ per gallon, compared to the full pass-through case. The E85/E10 price ratio is the same (it is necessary to attain the 600 million gallon level of E85 sales) but that price ratio is maintained in part by increasing the price of E10 in addition to discounting E85 by a slightly lesser amount. In this example the blender margins more than double, from 3¢ to 6.3¢ per gallon, and overall profits increase by about $4.4 billion per year. It is important to understand that this is not the cost of the RFS program, or of meeting the mandate, but rather the consumer burden experienced by a lack of competition at the blending level of the value chain.

The above analysis is not a prediction—indeed we would expect competitive pressures to restore margins to historic levels if the RVO were set beyond the blend step. In the transportation fuel market, competition at the retail level would erode the ability of blenders to retain RIN value in the form of higher blending margins. One possible explanation for the imperfect response of the market in 2013 is the fact that many transactions in the fuels market occur under term contracts whose pricing formulas may not yet incorporate mechanisms to reflect RIN values. If RIN values continue to remain material, we would expect to see new pricing formulas emerge that take RIN value into account as existing contracts expire and are subject to renegotiation. As more retailers begin to appreciate the role of RIN prices in influencing blending margins, they will apply pressure to receive a portion of that value in the prices that they pay. Correspondingly, retail price competition would tend to cause those discounts to, in turn, be passed on to consumers.

Lessons from 2013 RIN Prices

During 2013, elevated RIN prices did contribute to lower E85 prices and stimulated an expansion of E85 sales. This demonstrated that RIN value can be passed to consumers and that E85 provides a competitive pathway to expand the role of ethanol. This occurred primarily in the Midwest.[9] However, it also appears that E10 prices were elevated somewhat as blenders apparently did not pass the RIN values onto consumers, indicating some pricing power in the near term.

However, the RIN market of 2013 probably lacked liquidity and depth, in part because most of the RINs generated in blending are not transacted in the secondary market. If the RVO were set above the effective blend step, then non-Midwest (coastal) refiners and blenders who do not regularly transact in the RIN market, but currently lack distribution channels for E85, would have to purchase some RINs for compliance from Midwestern blenders. This would inject substantial liquidity and price transparency into the RIN market. Over time, and under a more

[9] See EIA *Today in Energy* September 19, 2013 "E85 Motor Fuel is Increasingly Price-Competitive with Gasoline in Parts of the Midwest" at for comparisons of E10 and E85 retail prices in selected states: http://www.eia.gov/todayinenergy/detail.cfm?id=13031#. These states were Iowa, Illinois, Indiana, Kentucky, Michigan, Minnesota, and Ohio.

predictable market, we would expect that RIN prices would convey more accurate information about the value of higher ethanol blends in meeting more ambitious mandates, and that supply margins would revert to historic norms.

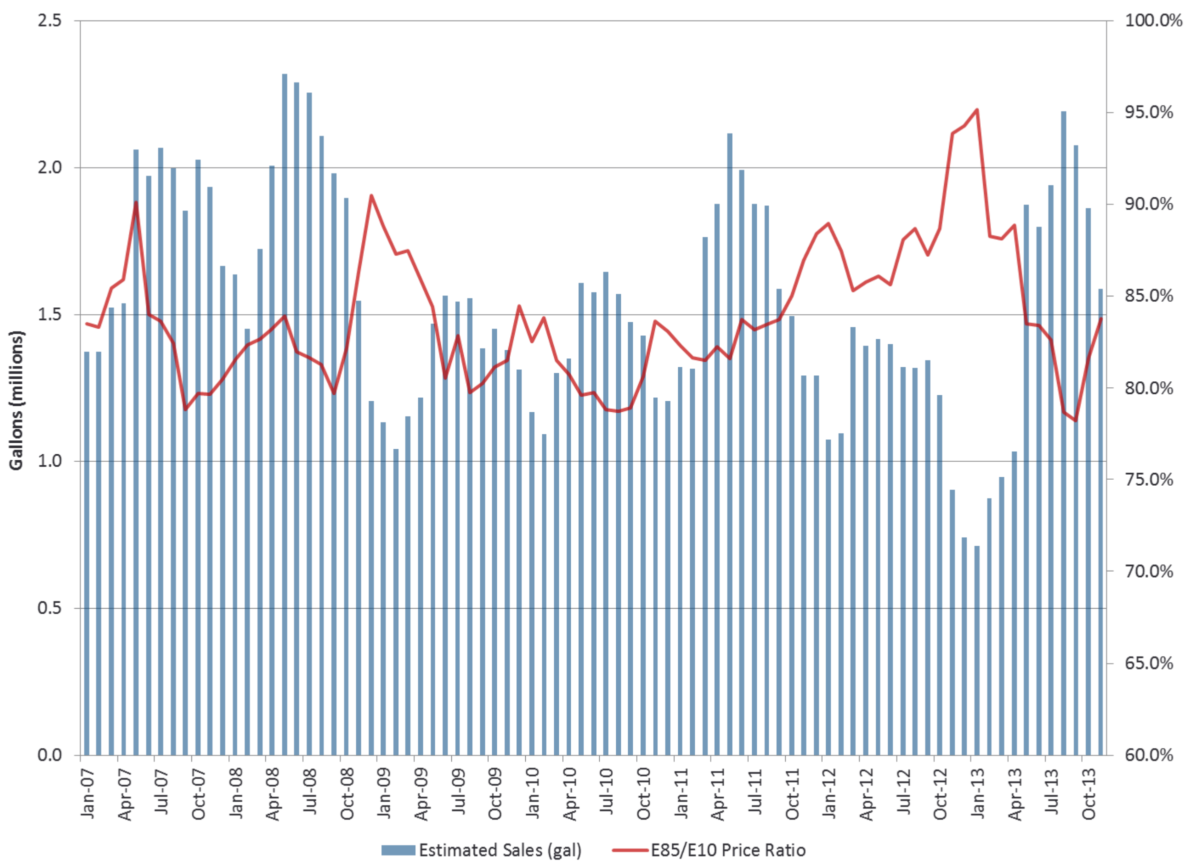
The RFS program is well designed, and relies on competitive conduct to deliver on the objectives at minimal consumer cost. Abrupt transitions from one regulatory state to another are often accompanied by a brief period of disequilibrium and high prices, which subsequently subside. For example, the Eastern U.S. NO_x allowance trading market began in March 2003 with initial prices in the $7,000 per ton range, which fell to about $2,500 by September 2003 and remained between $2,000 and $3,500 for several years. In the case of the RFS, competitive pressures should emerge to counteract the pricing power observed during the RIN price spike of 2013, and insulate consumers from unwarranted price increases if the volume mandates were expanded.

APPENDIX A

CONSUMER DEMAND FOR E85: THE MINNESOTA EXAMPLE

Because consumers respond to price signals, retail market conditions will determine E85 demand. This is most readily seen by using Minnesota as a case study, as monthly data on E85 sales volume and prices since 2007 are available. Minnesota currently has the most retail E85 outlets (about 350) of any state and over 300,000 FFVs registered. The Figure A-1 below shows monthly E85 sales volumes in gallons on bars (left scale) and a line showing the retail price ratio of E85 to regular E10 gasoline (right scale, where values less than one correspond to E85 prices below that of regular gasoline, not adjusted for energy content).

Figure A-1: Minnesota E85/Regular Gas Price Ratio vs. E85 Sales



Over the period January 2007 through November 2013, the average ratio between E85 and regular gasoline was 84%, and 2013 contained both the maximum observed value (95.1% in January) as well as the minimum observed value (78.2% in September). The figure shows that E85 sales volumes have a distinctly seasonal pattern—generally peaking in mid-year—and sales volumes appear to be related to relative prices of E10 and E85. The figure also suggests that, during 2007 and 2008, consumers were purchasing substantial volumes of E85 with little regard to relative prices, perhaps as "early adopters" influenced by significant marketing efforts. Some of these consumers may have abandoned the market (or simply become more price sensitive) when the E85/E10 ratio rose, mostly as a result of a sharp drop in E10 prices in late 2008. To better reflect current consumer behavior, we confine our statistical analysis to January 2009–November 2013 data (the last month available).

In order to isolate the effect of relative prices on monthly E85 sales, we conducted a regression analysis that took the form of:

$$LN\ (E85\ sales) = a + b1\ (pE85/pE10) + Year + quarter$$

The result of this regression is shown in Table A-1 below:

Table A-1: E85 Demand Regressions (Jan 2009 through Nov 2013)

VARIABLES	(1) Ln(Q_{E85})
E85:Regular Gasoline Price Ratio	-5.36***
	(0.51)
Q1 Dummy	-0.098**
	(0.038)
Q2 Dummy	0.075*
	(0.039)
Q3 Dummy	0.055
	(0.041)
Y2009 Dummy	-0.12***
	(0.043)
Y2010 Dummy	-0.24***
	(0.047)
Y2011 Dummy	0.066
	(0.043)
Y2012 Dummy	0.016
	(0.046)
Constant	18.7***
	(0.44)
Observations	59
Adjusted R-squared	0.827

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The regression explains about 83% of the variation in observed monthly sales volume, and most of the coefficients are significant. The regression coefficient on the E85/E10 price variable indicates that for every percentage point decrease in the E85/E10 price ratio, monthly sales volume was higher by 5.4%, a very substantial consumer response. To illustrate how responsive consumers are, consider that over the past year regular (87 octane) E10 prices in Minnesota averaged about $3.50 per gallon, while E85 prices averaged about $3.00. At those relative prices, an increase of only 5¢ per gallon of regular E10 *or* a price decline of only 4¢ per gallon of E85 would be sufficient to increase E85 sales by about 5%.[1]

The seasonality of sales is also quite pronounced, which must be taken into account when evaluating the impact of prices. For example, about 2.53 million gallons of E85 were sold during January through March of 2013, which rose to 4.71 million gallons sold during April through June, or an 86% increase. The "normal" seasonal sales increase according to the dummy variables is about 18% (Q1 is 10% below the annual average, while Q2 is 8% above). So, roughly 68% of the increase could be explained by other factors, chiefly the change in the E85/E10 price ratio that went from about 95% in January to about 83% in June. Since the actual change in volumes exceeds the change predicted by the price ratio alone, other factors may have come into play. We understand that at least one large service station network made substantial E85 price discounts, and made a concerted marketing push for E85. It appears that Minnesota FFV customers were receptive, suggesting that E85 sales growth can be quite brisk when retailers have an incentive to aggressively market E85 to customers.

Using Minnesota Retail Data to Construct the US E85 Demand Curve

The model described above does not take into account the constraint on Minnesota E85 consumption due to the size of the FFV fleet. To account for this constraint, we developed a choice model to explain how Minnesota FFV owners choose between E85 and E10 when filling up their gas tanks.

The model assumes that a typical Minnesota FFV owner makes the decision to fill up with either E85 or E10 depending on a single major factor—the relative prices of the two products (*e.g.* the E85/E10 price ratio). Using the Minnesota data on E85 sales volume and prices, as well as data on per-vehicle motor fuel consumption and estimates of the number of registered FFVs over time, we computed the monthly energy-adjusted "market share" of E85.[2] This market share for the period 2009 through 2013 is displayed in Figure A-2.

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1 This regression treats the monthly Minnesota data as cross section data in order to associate different E85/E10 price ratios with corresponding sales volume for demand curve estimation. When month-to-month changes in variables were used to estimate consumer responses to changes over time (without the quarterly or annual dummy variables), the coefficient on price ratio was nearly identical at -5.1% and the R^2 was 0.534.

2 The E85 "market share" we computed is adjusted for the different energy content of one gallon of E85. If, for instance, the E85 market share were 15% in a given month, then 15% of the energy used by FFVs in that month came from E85 (and the other 85% of the energy is assumed to have come from E10). Because

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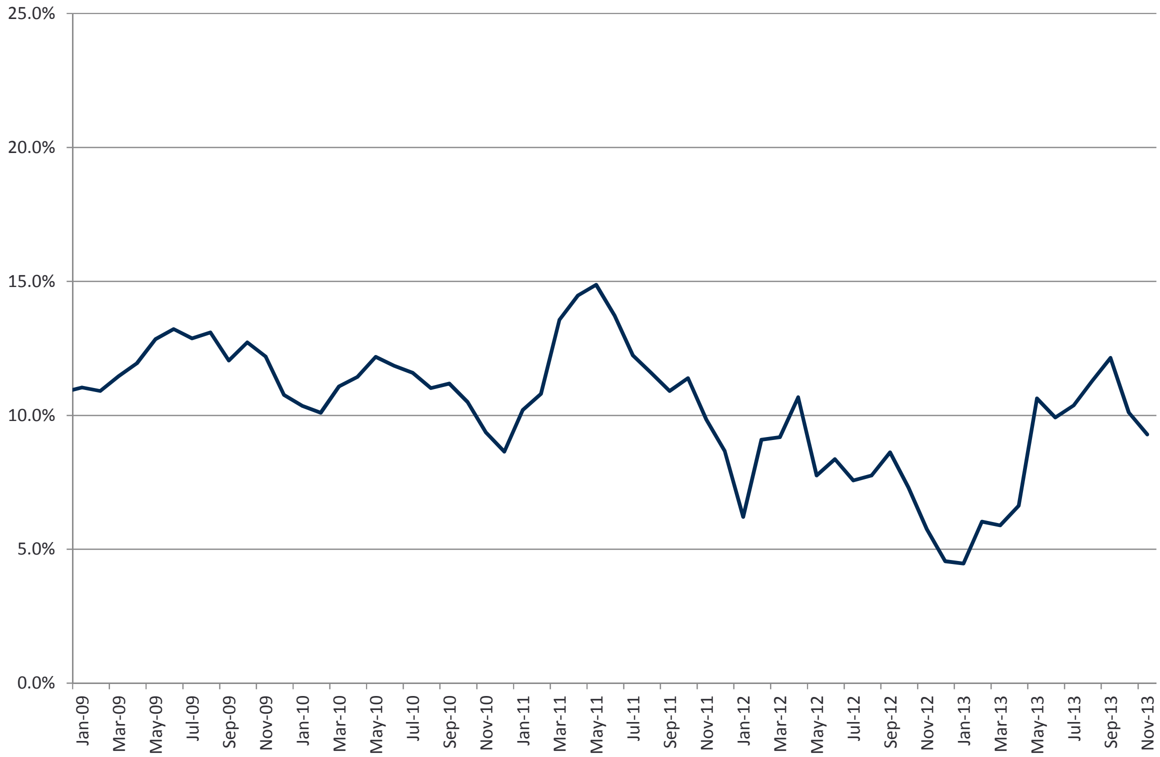
Figure A-2: E85 Market Share Among Minnesota FFV Users (Energy Equivalent Basis)



We then used the data to estimate the relationship between the E85 market share and the E85/E10 price ratio. Because we are interested in the behavior of consumers at the annual level, we have excluded quarterly dummy variables from this regression. The results of this estimation are presented in Table A-2.

Continued from previous page

one gallon of E10 has greater energy content than one gallon of E85, then the amount of E85 consumed by FFVs as a percentage of overall gallons of motor fuel will be strictly greater than 15%.

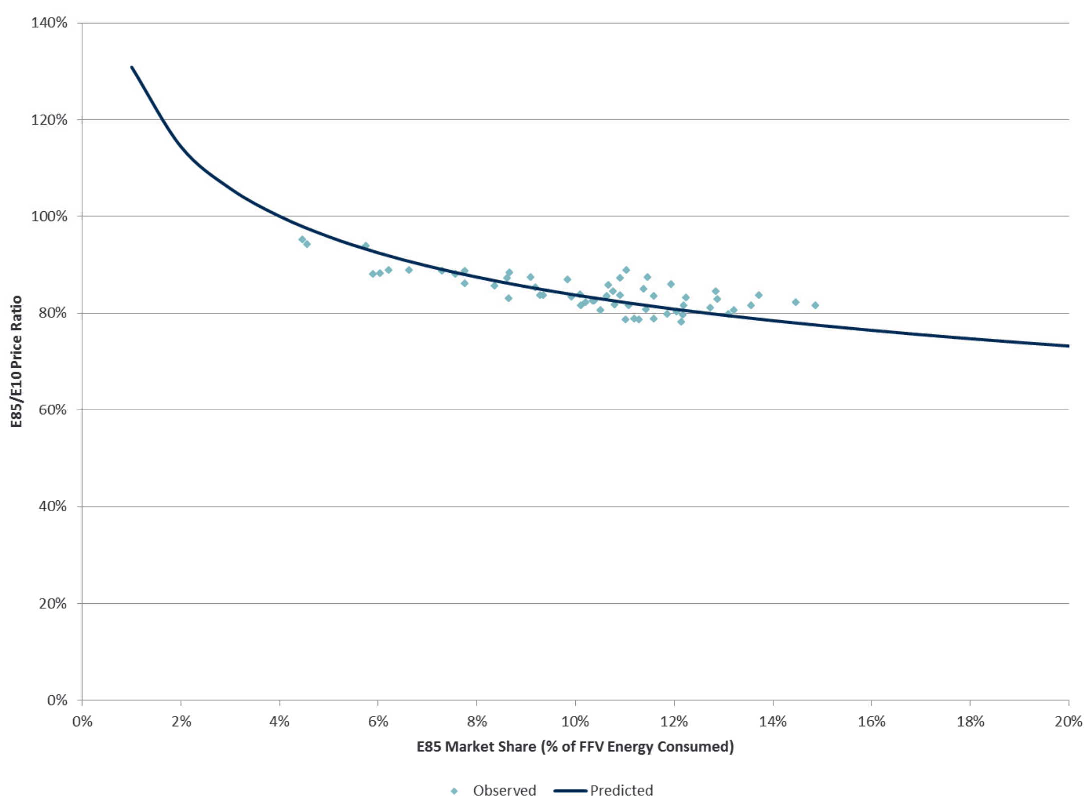
Table A-2: E85 Demand Estimation (Jan 2009 through Nov 2013)

VARIABLES	(1) Ln(Market Share)
Log E85:E10 Price Ratio	-5.161***
	(0.460)
Constant	-3.228***
	(0.080)
Observations	59
R-squared	0.7253

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

As before, we observe a strong inverse relationship between the E85 market share and the E85/E10 price ratio. The regression coefficient on the E85/E10 price ratio of -5.16 represents the elasticity of demand. At the most recently observed levels of the price ratio and the market share (November 2013), the interpretation of this coefficient is that if the price ratio were to decrease by one percentage point (from 84% to 83%), then the E85 market share would increase from 9.3% (1.59 million gallons of E85 in November 2013) to nearly 9.9% (1.68 million gallons of E85 in November 2013). The demand curve is plotted in Figure A-3 below.

Figure A-3: Minnesota E85 Demand Curve



A key strength to this approach is that the model describes individual consumer behavior with respect to near-substitutes and essentially homogenous goods; therefore, it may reasonably be applied to contexts outside of Minnesota (*e.g.* the United States). It is important to note, however, that the model implicitly takes into account the extent of E85 retail infrastructure in Minnesota. This means that the demand curve model may not describe consumer behavior across the United States where accessibility to retail E85 is lower. Therefore, we made the adjustments described in the report to account for the availability of E85 filling stations across the United States to construct a nationwide annual demand curve for E85.

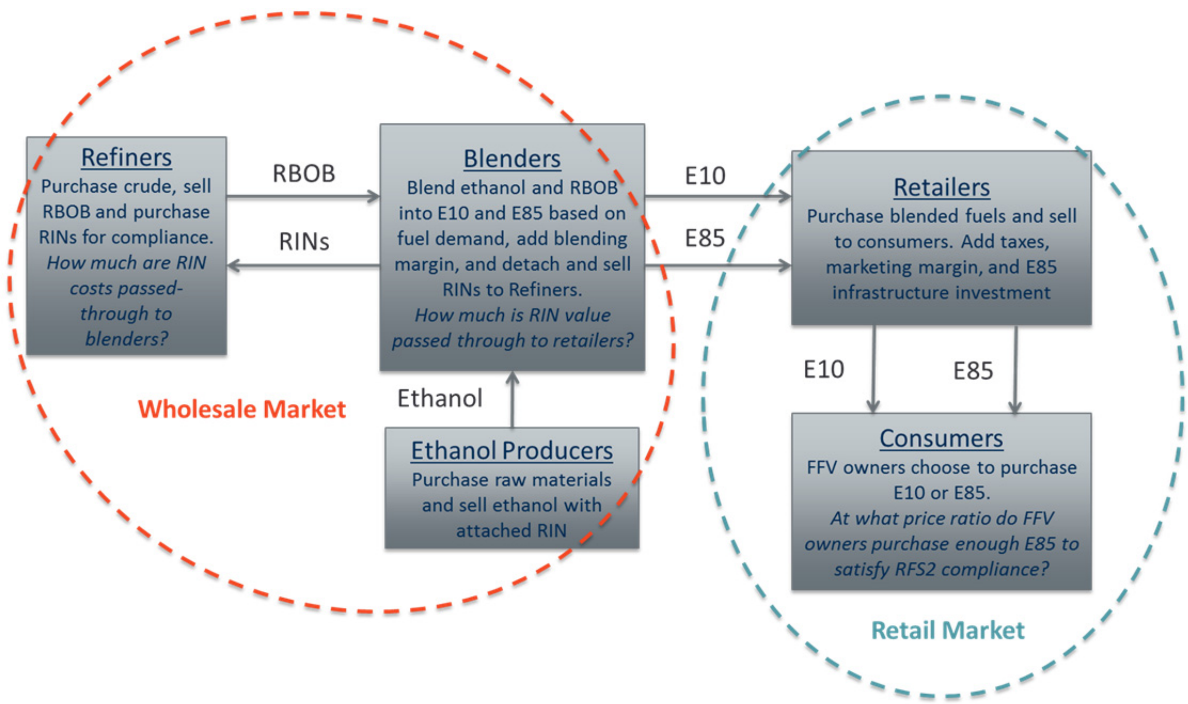
APPENDIX B
RIN PRICING ANALYSIS FRAMEWORK

Meeting expanded Renewable Volume Obligations (RVOs) in future years will require that increasing levels of renewable fuels are blended into motor fuels at the wholesale level and sold to consumer at the retail level. A fundamental assumption of our analysis is that E85 becomes the marginal fuel in meeting the future RFS2 mandates above the E10 "blend wall." In other words, an increase in the RVO will require additional E85 sales.

Modeling how future RIN prices could incentivize rising E85 sales requires examining the entire fuel supply chain—from the refiners to the retailers. Since additional E85 sales will require a decrease in retail prices for E85 relative to E10, a framework for analyzing RIN prices across the supply chain is necessary. If refiners increase their demand for RINs and are thus willing to pay more for them, the quantity of RINs demanded will only be available if blenders, marketers, and retailers down the supply chain price E85 (and E10) accordingly to incentivize additional sales.

To simplify the complex interactions among multiple market participants, we assumed the structure and relationships across the motor gasoline supply as shown in Figure B-1.

Figure B-1: RIN Supply Chain Framework



In our analysis, we assume overall fuel demand is equivalent to assumptions made in the EPA Notice of Proposed Rulemaking for the 2014 Renewable Fuel Standards, as shown in Table B-1.[1]

Table B-1: Fuel Demand Assumptions
(180 Million Gallons per Year E85 Case)

Proposed 2014 RVO	**Units**	**Value**
Total Demand	*bgy*	179.8
Total Gasoline Demand	*bgy*	132.7
Total Diesel Demand	*bgy*	47.1
Renewable Demand (Ethanol-equiv)	*bgy*	15.2
Renewable Gasoline	*bgy*	13.1
Renewable Diesel	*bgy*	1.4
Renewable Diesel (Ethanol-equiv)	*bgy*	2.1
Fossil Demand	*bgy*	164.6
Fossil Gasoline	*bgy*	119.5
Fossil Diesel	*bgy*	45.7
Proposed RVO	*%*	**9.2%**
Gasoline RVO Rate	*%*	11.0%
Diesel RVO Rate	*%*	4.6%
Proposed Ethanol in Gasoline	*%*	**9.9%**

As the percentage of renewable diesel fuels (*e.g.*, biodiesel) in the diesel pool is expected to be less than the RVO, the gasoline pool must blend renewable gasoline (*e.g.*, ethanol) into petroleum-based gasoline at a rate higher than the RVO mandates. To reflect that difference, the effective RVO rate for each fuel-type is calculated in Table B-1. The "effective RVO" rate for the gasoline pool in 2014 is expected to be 11.0% with the volume percentage of ethanol in gasoline of 9.9%, just below the 10% value considered the E10 "blend wall."

To keep the total energy demand constant in our analysis while increasing E85 sales, additional renewable gasoline consumption is assumed to displace oil-based gasoline at a rate equal to their energy content. The EPA has assumed 180 million gallons of E85 sales in the previous table. An increase to 600 million gallons would result in adjustments to the proposed 2014 Renewable Fuel

[1] The Renewable Volume Obligation (RVO) set by the EPA is calculated by dividing the gallons of renewable fuel by the gallons of petroleum-derived fuel. The gasoline RVO and diesel RVO are calculated in Table B-1 in the same way. On the other hand, the Ethanol in Gasoline is calculated by dividing the gallons of ethanol by the total gallons of gasoline.

Standard as shown in Table B-2. The effective RVO for gasoline is increased to 11.3% and the ethanol in gasoline value is now 10.1%.

Table B-2: Fuel Demand Assumptions
(600 Million Gallons per Year E85 Case)

Adjusted 2014 RVO	**Units**	**Value**
Renewable Gasoline Increase	*bgy*	0.31
Ethanol in 180 mgy E85	*bgy*	0.13
Ethanol in 600 mgy E85	*bgy*	0.44
Fossil Gasoline Decrease	*bgy*	0.21
Total Demand		179.9
Total Gasoline Demand	*bgy*	132.8
Total Diesel Demand	*bgy*	47.1
Renewable Demand (Ethanol-equiv)	*bgy*	15.5
Renewable Gasoline	*bgy*	13.4
Renewable Diesel (Ethanol-equiv)	*bgy*	2.1
Fossil Demand	*bgy*	165.1
Fossil Gasoline	*bgy*	119.3
Fossil Diesel	*bgy*	45.7
Adjusted RVO	*%*	**9.4%**
Gasoline RVO Rate	*%*	**11.3%**
Diesel RVO Rate	*%*	**4.6%**
Adjusted Ethanol in Gasoline	*%*	**10.1%**

As discussed in Appendix A, an increase in E85 sales would require adjustments in the relative retail prices of E85 and E10 to provide sufficient incentive for FFV owners to purchase E85 instead of E10. A higher RVO, along with the necessary relative retail prices of E85 and E10, impose new constraints at opposite ends of the fuel supply chain, which are equilibrated by the RIN price.

We base our analysis on how market players are expected to act in a mature, efficient market. In this framework, we assume that the supply and demand of RINs can efficiently price the fuel products while allowing market participants to maintain their previous level of profit margins. Due to the change in the fuels mix with an increasing RVO, overall profits for some market players inevitably change, with reduced profits for refiners and increased profits for ethanol producers.

In this analysis, we assume the profit margins of refiners and ethanol producers are included in the futures market 2014 prices for RBOB gasoline and denatured ethanol. We assume these products would be sold at the average of 2014 futures if there were no RFS mandate, as shown in Table B-3.

Table B-3: Futures Prices as of January 21, 2014

Delivery Date	CBOT Denatured Fuel Ethanol Futures *$/gallon*	RBOB Gasoline Futures *$/gallon*
Feb-14	1.880	2.6282
Mar-14	1.813	2.6395
Apr-14	1.779	2.8199
May-14	1.755	2.8175
Jun-14	1.725	2.7984
Jul-14	1.720	2.7683
Aug-14	1.696	2.7258
Sep-14	1.672	2.6864
Oct-14	1.654	2.5431
Nov-14	1.635	2.5114
Dec-14	1.625	2.4938
2014 Avg.	**1.723**	**2.676**

We assume profit margins for blenders and retailers (as well as state and federal taxes[2]) are added on a volumetric basis at historic rates as shown in Table B-4. As E85 sales require investment in new infrastructure for handling, storage, and sales, we have also included a volumetric adder to the price of E85 sales.

[2] The federal excise tax on retail motor gasoline is currently 18.4¢ per gallon. As state taxes will vary state-to-state, we are assuming for illustration purposes that the total tax is 50¢ per gallon.

Table B-4: Blender and Retailer Assumptions

Component	Units	Value
Total E10 Margin	**$/gal**	**0.58**
Blender Margin	$/gal	0.03
Taxes	$/gal	0.50
Retail Margin	$/gal	0.05
Total E85 Margin	**$/gal**	**0.68**
E85 Equipment Adder	$/gal	0.10

To ensure that Refiners retain a constant profit margin, we assume that Refiners sell gasoline blendstock (RBOB) to the Blenders at a higher price than they would without the RVO mandate. The higher price allows them to recover the costs of producing the RBOB as well as purchasing the quantity of RINs to meet their RVO. The price at which the Refiner sells RBOB to the Blenders is shown in:

$$P_{RBOBwRVO} = P_{RBOB} + RVO \times P_{RIN}$$

Equation 1

As our analysis is focused solely on the motor gasoline market since there is insufficient biodiesel to blend diesel fuel at the RVO, we assume that additional RINs are obtained through the sale of ethanol at levels above the RVO, equal to the effective gasoline RVO as shown in Table B-1. In all equations, the RVO can be assumed to be the "gasoline RVO."

Blenders, on the other hand, will now have an additional source of revenue from the sale of the RINs to the Refiners. As we assume Blenders earn their profit margins through the volumetric adder explained above, the revenues from the RIN sales are directly subtracted from the price of ethanol. Thus the effective price of ethanol with the RVO requirements becomes:

$$P_{EtOHwRFS2} = P_{EtOH} - P_{RIN}$$

Equation 2

The profit margins captured by the Blenders and the Retailers are added on a volumetric basis as are the taxes and, for E85, an E85 equipment adder to cover the cost of additional infrastructure to distribute and sell E85.

$$PM_{E10} = Tax + PM_{Blender} + PM_{Retailer}$$

Equation 3

$$PM_{E85} = Tax + PM_{Blender} + PM_{Retailer} + Equipment_{E85}$$

Equation 4

Based on these components, the prices of E10 and E85 sold to customers at retail stations are calculated as follows:[3]

$$P_{E10} = 90\% \, (P_{RBOB} + RVO \times P_{RIN}) + 10\% \, (P_{EtOH} - P_{RIN}) + PM_{E10}$$

Equation 5

$$P_{E85} = 15\% \, (P_{RBOB} + RVO \times P_{RIN}) + 85\% \, (P_{EtOH} - P_{RIN}) + PM_{E85}$$

Equation 6

As can be seen in the preceding formulas, the RIN credits increase the price of the RBOB and decrease the effective price of the ethanol. In this way, the RINs will adjust the prices at the pump to the point at which enough volumes of E10 and E85 are sold to meet the Refiners' demand for the RINs created by the RFS2 requirements.

Finally, as explained in more detail in Appendix A, we assume the E85 price at the pump must be at a sufficient discount to E10 to sell enough E85 to meet the RVO.

$$Disc_{E85} = \frac{P_{E85}}{P_{E10}}$$

Equation 7

Plugging in Equation 5 and Equation 6 into Equation 7, we can calculate the expected RIN price.

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[3] For demonstration purposes, Equation 5 and Equation 6 are shown here such that E10 and E85 are blended with the maximum allowable ethanol content (*e.g.*, E85 is 85% ethanol). As the actual percentage will vary seasonally, we assume that the annual average ethanol content of E85 is 74% ethanol in our analysis, in line with the EPA's assumption.

$$P_{RIN} = \frac{(15\%P_{RBOB} + 85\%P_{EtOh} + PM_{E85}) - Disc_{E85} \times (90\%P_{RBOB} + 10\%P_{EtOh} + PM_{E10})}{(85\% - 15\% \times RVO) - Disc_{E85} \times (10\% - 90\% \times RVO)}$$

Equation 8

In our analysis, we also take a closer look at how decisions by market players in the new RIN market may not conform to the assumption of perfect competition. If Refiners do not fully pass-through their additional costs of purchasing RINs to the blenders, their profits and the costs of the RFS2 program to downstream parties will be reduced. In a similar way, if blenders do not fully pass-through the value of the RINs in the "effective price" of ethanol, their profits and the cost of the RFS2 program to downstream parties will increase. In these cases, our analysis of RIN price becomes:

$$P_{RIN} = \frac{(15\%P_{RBOB} + 85\%P_{EtOh} + PM_{E85}) - Disc_{E85} \times (90\%P_{RBOB} + 10\%P_{EtOh} + PM_{E10})}{(85\% \times PT_{Blend} - 15\% \times RVO \times PT_{Ref}) - Disc_{E85} \times (10\% \times PT_{Blend} - 90\% \times RVO \times PT_{Ref})}$$

Equation 9