CARD Policy Briefs

Center for Agricultural and Rural Development
IOWA STATE UNIVERSITY

CARD Policy Brief 13-PB 11
August 2013

Price It and They Will Buy: How E85 Can Break the Blend Wall

by Bruce Babcock and Sebastien Pouliot

Bruce Babcock holds the Cargill Chair in Energy Economics and Sebastien Pouliot is an Assistant Professor of Economics at Iowa State University.

Published by the Center for Agricultural and Rural Development, 578 Heady Hall, Iowa State University, Ames, Iowa 50011-1070; Phone: (515) 294-1183;
Fax: (515) 294-6336; Web site: www.card.iastate.edu.

Partial support for this work is based upon work supported by the National Science Foundation under Grant Number EPS-110 1284. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of the National Science Foundation.

Funding for this project was also provided by the Biobased Industry Center and the USDA Policy Research Center at Iowa State University.

Executive Summary

Biofuel mandates in 2014 and 2015 are scheduled to push ethanol consumption beyond the E10 blend wall—the amount of ethanol that can be easily consumed in the United States in a 10 percent ethanol and 90 percent gasoline blend. Numerous interest groups and academics are calling on the Environmental Protection Agency to cut back on scheduled mandate increases because of the uncertainty of the cost and exactly how ethanol consumption can be increased beyond E10. The uncertainty centers around the position of the "beyond-E10" demand curve for ethanol, which simply measures the response of ethanol consumption to lower ethanol prices at ethanol quantities above 13 billion gallons. Some oil companies argue that there is no demand for ethanol above 13 billion gallons so that it is physically impossible for them to mandate using ethanol. Others argue that there may be a demand curve, but that possible consumption quantities are quite limited.

The reason why there is uncertainty about the position of ethanol demand above 13 billion gallons is because we have no US data to observe consumption above the E10 blend wall. However, insight into the question of what the demand curve might look like can be obtained by estimating the demand for E85 by owners of flex vehicles using data from Brazilian drivers who choose between ethanol and gasoline largely based on relative costs per mile. A key difference between Brazil and the United States is that in Brazil every station sells both ethanol and gasoline, whereas US drivers must search for a station that sells E85. We account for this difference by calculating the additional distance that must be traveled by owners of US flex vehicles to a station that sells E85. The further the distance the greater the fuel savings must be from E85.

The resulting demand curve for ethanol above the E10 blend wall suggests E85 consumption of about one billion gallons if E85 were priced to generate a six percent reduction in fuel costs. If the price were lowered further to generate a 15 percent reduction then about two billion gallons could be consumed, and a 30 percent reduction would be needed to induce three billion gallons of consumption. These estimates do not account for the increase in the size of the flex vehicle fleet in 2013 and 2014 or the likely increase in the number of stations that will find E85 an attractive fuel to sell.

These results suggest that rather than being a physical barrier to increased ethanol consumption, the E10 blend wall is an economic barrier that can be overcome by increasing the incentive for drivers to use E85 to fuel their vehicles. Current RIN (Renewable Identification Numbers) prices are high enough to achieve modest increases in ethanol consumption above 13 billion gallons and to create incentives to increase the ability to consume lower-carbon ethanol in 2016 and beyond.

Price It and They Will Buy: How E85 Can Break the Blend Wall

By Bruce Babcock and Sebastien Pouliot

The Environmental Protection Agency (EPA) is poised to release its draft rule for mandated volumes of biofuels for 2014. The key decision that EPA will make in this rule is whether to follow precedence and propose volume mandates that will force US ethanol consumption beyond levels that can easily be met using a blend of 10 percent ethanol and 90 percent gasoline. This so-called E10 blend wall stands at about 13 billion gallons of ethanol consumption. To date, EPA has hewed closely to biofuel volumes specified in the Energy Independence and Security Act. If it does so again, then the 2014 mandate for conventional biofuel, which is met primarily by corn ethanol, will rise to 14.4 billion gallons, and the advanced mandate, which is met primarily by biodiesel and sugarcane ethanol, will rise to 3.75 billion gallons. Depending on what EPA decides about biodiesel, which has its own mandate, EPA could propose total ethanol volume mandates that imply, given banked RINs, 16.2 billion gallons in 2014. EPA has flexibility in setting the advanced biofuel mandates because cellulosic ethanol is simply not available in sufficient quantities to meets its mandates. Some expect EPA to use this flexibility to reduce the advanced mandate below 3.75 billion gallons which would require consumption of less than 16.2 billion gallons in 2014.

Mandated volumes of biofuels have been met so far mainly through a combination of biodiesel and ethanol consumed as E10. In addition, in 2013, mandates will be partially met by a drawdown of the blending credits that have accumulated from previous years when consumption of ethanol exceeded mandated levels. These credits are called RINs (Renewable Identification Numbers). The drawdown in the number of banked RINs in 2013 has reduced the excess RINs that are available to meet mandated volumes in 2014 and 2015. This means that almost all of the mandated volumes in 2014 and 2015 will have to be met by actual consumption of biofuels, which will require ethanol consumption levels that exceed what can be consumed in E10.

The two ethanol blend rates approved by EPA that can be used to increase ethanol consumption beyond the E10 blend wall are E15 and E85. E15 is approved for use by 2001 and later model year cars. E85, which contains no more than 85 percent ethanol, is approved for use by flex fuel cars. Because each gallon of E15 displaces one gallon of E10, a gallon of E15 consumption only increases ethanol consumption by 0.05 gallons. Thus, it takes 20 billion gallons of E15 consumption to increase ethanol consumption by one billion gallons. On average, if a gallon of E85 contains 75 percent ethanol, then each gallon of E85 consumption increases ethanol consumption by 0.65 gallons. Thus, it takes 1.54 billion gallons of E85 consumption to increase ethanol consumption by one billion gallons. At least in the short-run and with modest volumes, it seems likely that E85 will be the least-cost approach to moving beyond the blend wall because of the large market penetration of E15 that would have to take place.

The cost and feasibility of increasing ethanol consumption beyond E10 in 2014 and beyond using E85 depends on a number of factors including the cost of producing ethanol, the number and location of flex vehicles, the number and location of gas stations that sell E85, and the economic incentives required to induce retail outlets to install additional E85 pumps and to induce consumers to buy flex vehicles. In this paper we explore these issues in some depth and provide an estimate of the US demand curve for ethanol consumption in E85 using data that establishes a link between the location of stations that sell E85 and the location of flex vehicles. Our estimates indicate that it is feasible to meet 2014 and 2015 biofuel mandates with expanded E85 consumption given existing numbers of flex vehicles and stations that sell E85. Not surprisingly, the key variable in expanding E85 consumption is to lower its price. We begin with an overview of how the current policy of using tradable RINs can facilitate the required drop in price of E85 that will in turn increase E85 consumption.

The Market for RINs and E85

RINs are an instrument created by EPA to record and verify compliance with biofuel mandates. A key role of RINs is to minimize the total costs of complying with biofuel mandates. As such, the role of RINs is similar to the role tradable pollution permits play in minimizing the costs of pollution abatement.

RINs are a commodity just like corn or crude oil. Like corn and crude, RINs are storable so that RINs purchased in one year can be consumed in the future. As a tradable commodity, RIN prices are determined by the basic laws of supply and demand. When the current demand for RINs rises, so too does the RIN price, but an increase in the supply of RINs decreases their price. If it is anticipated that the demand for RINs will increase in the future, then the current price of RINs rises as buyers try to buy inexpensive RINs today and bank them for use tomorrow.

The total supply of RINs in a year equals the number of RINs that are in storage at the beginning of the year plus the number of RINs that are produced during the year. RINs are produced whenever qualifying biofuels are produced. Thus the only way to increase the supply of RINs is to increase the production of biofuels.

The only source of demand for RINs is the requirement that producers and importers of transportation fuels meet their obligations to use biofuels. To show EPA that they have met their requirement, these obligated parties give EPA the RINs that they have accumulated during the year.

Blenders buy ethanol from ethanol producers and blend it with gasoline to create a finished transportation fuel. A RIN is assigned to each batch of ethanol and typically follows the ethanol to the blender. If a blender is also a producer of gasoline then the blender will likely keep the RIN and give it to EPA to show that it met its obligation. However, most blenders are not obligated parties so most RINs are sold on the RIN market. When obligated parties need RINs, they turn to the RIN market and buy from blenders.

When ethanol producers sell ethanol they are actually selling two products: ethanol and RINs. Each has its own independent value. Ethanol has value as a transportation fuel. RINs have value because obligated parties need them to meet the requirements of the Renewable Fuels Standard. The relative contribution of RINs and ethanol to the plant price of ethanol can vary dramatically. If the value of ethanol as a transportation fuel is high enough to cover the production costs of ethanol producers, then the supply of RINs may be greater than the demand for RINs. When this occurs, the price of RINs falls to near zero and the plant price of ethanol is determined solely by the value of ethanol as a transportation fuel.[1] When the demand for ethanol as a transportation fuel is saturated,

[1]Subsidies also affect the plant price of biofuels. Ethanol prices were boosted by the blenders tax credit until it expired at the end of 2011. Biodiesel continues to receive a taxpayer subsidy of $1.00 per gallon.

its incremental value can fall dramatically. If biofuel mandates push consumption beyond this saturation point, then the market value of ethanol will head towards zero and the plant price of ethanol is determined primarily by the price of RINs, not by the value of ethanol.

The plant price of ethanol therefore equals the transportation value of ethanol plus the market price of RINs. Another way of arranging this equality is to say that the price of RINs equals the plant price of ethanol minus the incremental value of ethanol as a transportation fuel. As market prices reflect underlying market forces, if there is production of ethanol in excess of the mandates, the plant price of ethanol reflects the cost of producing additional ethanol. In contrast, when ethanol mandates determine how much ethanol is consumed, the price of RINs equals the cost of producing another million gallons of ethanol minus the value of the additional million gallons as a transportation fuel.[2]

Suppose that the ethanol mandate is 14 billion gallons and the incremental value of ethanol as a transportation fuel in an E10 blend wall is zero for any quantity above 13 billion gallons. Thus, the plant price of ethanol will equal the RIN price, which will equal the cost of producing the 14 billionth gallon of ethanol.[3] Obligated parties would be paying ethanol plants their full cost of producing a product for which there is no value. Clearly, this situation creates a strong incentive for obligated parties to create value out of the extra billion gallons of ethanol because even 10 cents per gallon of value decreases their compliance costs by $100 million.

One billion gallons of ethanol blended in an E85 blend of 75 percent ethanol and 25 percent gasoline creates 1.33 billion gallons of fuel. Suppose that obligated parties believe that this fuel could be sold to owners of flex vehicles but only if was heavily discounted relative to E10, which we assume is priced at $3.60 per gallon. For example, suppose the 1.33 billion gallons of E85 could be sold if its retail price were $2.16 per gallon. At this price, the cost per mile of fuel using E85 is about 20 percent lower than using E10. Subtracting an average wholesale to retail price markup of $0.75 per gallon implies a wholesale price of E85 of $1.41 per gallon. With wholesale gasoline at $2.85 per gallon, this implies that the wholesale value of ethanol as a transportation fuel is $0.93 per gallon.

Compared to the situation where the extra billion gallons of ethanol has no value, this E85 scenario reduces RIN prices by $0.93 per gallon because the value of ethanol as transportation fuel increased by this amount. Of course obligated parties would prefer not to have to turn in the billion additional RINs to EPA, but if they have to they are $930 million better off with 1.33 billion gallons of E85 than without.

This example shows how the market for RINs creates a mechanism for meeting a volume mandate at least cost. The least-cost solution is the one that maximizes the incremental value of ethanol as a transportation fuel because a higher transportation value lowers RIN prices. Just how low RIN prices can go in the short-run if EPA pushes mandates beyond the E10 blend wall depends on the cost of producing ethanol, the price of

[2] The ability to bank and borrow RINs means that the current price of RINs may not reflect the current difference between production costs and transportation values but rather the anticipated future difference. For simplicity we focus on RIN prices as reflecting the current difference only.
[3] Being a hypothetical example, we are silent about exactly where or how the extra billion gallons of ethanol is consumed.

gasoline, how much ethanol is sold as E85, and on how much E85 needs to be discounted to induce owners of flex vehicles to fill up with E85. Over a longer time period, the required discount will be reduced as more retail outlets sell E85 and more people buy flex vehicles. However, enough data exists today to calculate likely RIN prices and discounts that will be needed to meet possible 2014 and 2015 ethanol mandates.

Pricing E85 to Increase Ethanol Consumption

Brazilian drivers have more than 10 years of experience in deciding whether to fill up their flex fuel cars with ethanol or gasoline. The key factor for most drivers is fuel cost per mile traveled. When this cost is lower with ethanol, they fill up with ethanol. When it is lower with gasoline, they choose gasoline. Of course some drivers prefer ethanol and use it even if cost per mile is higher than gasoline, and some drivers dislike ethanol so much that they continue to use gasoline even when it increases their costs. Still, cost per mile of ethanol relative to gasoline is a good benchmark to use to determine the proportion of Brazilian drivers who use ethanol.

One advantage that Brazilians have is that every filling station sells both ethanol and gasoline so it is easy to switch fuel. US drivers who want to use E85 have to seek out one of the 3,000 stations in the country that sell E85. US drivers also face the disadvantage that the cost per mile driving on E85 has been significantly higher than driving on E10. For these two reasons, sales of E85 have been quite low. It will take some time for more stations to install the equipment needed to sell E85 and for consumers to buy more flex vehicles, but the price of E85 will fall if EPA adopts biofuel volumes that push ethanol consumption past the E10 blend wall.

Calculating the fuel cost per mile of E85 relative to E10 is straightforward. Cost per mile equals the price of fuel expressed in $ per gallon divided by the fuel efficiency of the car measured in miles per gallon. The fuel efficiency of a car running on an ethanol-gasoline blend will typically reflect the energy content of the blend. Ethanol contains about two-thirds the energy value of gasoline. Thus, the ratio of miles per gallon with E85 relative to E10 is 0.759, 0.777, or 0.793 when E85 contains 80, 75, or 70 percent ethanol, respectively. Because these fuel efficiency ratios are so close, we concentrate on E85 that contains 75 percent ethanol. The fuel efficiency ratios facilitate calculation of relative cost per mile for E85 and E10. The example above assumed a price for E10 of $3.60 per gallon and a price of E85 of $2.16 per gallon. With these prices, the cost per mile of E85 is 22.8 percent lower than the cost per mile of E10 (that is, .228 = 1 - (2.16/0.777)/3.6).

The retail price of E85 depends on a host of factors including the wholesale prices of gasoline and ethanol, the demand for E85, the amount of competition in fuel sales, taxes, transportation costs and retail sales costs. An approximation of these costs can be obtained by fitting a line to a scatterplot of weekly national average wholesale and retail gasoline prices since January 2007. The equation of the line is Retail Price =0.97*Wholesale price + 0.754. This simply means that when the wholesale gasoline price is $2.80 per gallon, the national average retail gasoline price is about $3.47 per gallon.

If we make the assumption that the wholesale price of a blended fuel equals the blend-weighted average of the wholesale price of ethanol and the wholesale price of gasoline, then for any wholesale ethanol and gasoline price we can calculate the approximate retail prices for E85 and E10, from which the fuel price ratio facing consumers can be calculated.[4] Table 1 shows percentage change in fuel cost per mile from E85 for different wholesale ethanol and gasoline prices. For a given ethanol price, an increase in the gasoline price increases the advantage (or decreases the disadvantage) of E85. The wholesale price of ethanol that equates cost per mile traveled is about $1.27 per gallon with $2.30 gasoline, $1.60 per gallon with $2.80 gasoline, and $1.95 per gallon with $3.30 gasoline. A wholesale ethanol price of about $0.75 per gallon is needed to generate a 20 percent fuel cost savings with $2.80 gasoline.

Table 1. Percentage decrease in Cost per Mile from E85 for Different Wholesale Gasoline and Ethanol Prices

	Gasoline ($/gal)		
Ethanol ($/gal)	2.30	2.80	3.30
0.00	39%	42%	45%
0.25	31%	36%	39%
0.50	23%	29%	33%
0.75	16%	22%	27%
1.00	8%	16%	21%
1.25	1%	9%	16%
1.50	-6%	3%	10%
1.75	-13%	-3%	4%
2.00	-20%	-10%	-1%
2.25	-27%	-16%	-7%
2.50	-34%	-22%	-12%
2.75	-41%	-28%	-17%
3.00	-47%	-33%	-22%

Source: Calculated by authors.
Note: A positive value means that the cost per mile of E85 is lower than the cost per mile of E10.

The ethanol prices in Table 1 can either be interpreted as what the wholesale price must be to provide a given cost per mile advantage (or disadvantage) to E85 or what the transportation value of ethanol has to be to give this advantage. In the latter case, the actual wholesale price would then be this transportation value plus the RIN price. Because the RIN price equals the difference between ethanol plant's production cost and the transportation value, the Table 1 numbers can be used to calculate the RIN price that is required to generate any needed change in fuel cost per mile traveled for any given level of ethanol production cost. As shown next, because the cost of producing ethanol is primarily determined by the price of corn, we can calculate RIN prices that are needed given a price of corn and a target change in fuel cost from E85.

Impact of Corn Prices on Required RIN Prices

The difference between ethanol production cost and the transportation value of ethanol is the RIN price. The cost of producing ethanol depends on a number of factors, but by far the most important factor is the price of corn. Other variable production costs include the cost of natural gas, enzymes, labor, water and electricity. Production costs per gallon vary across ethanol plants because of differences in plant efficiency and location. When calculating production cost it is important to account for the revenue stream generated by the sale of distillers grains.

The relevant production cost needed to calculate RIN values is the production cost of the incremental gallon of ethanol produced to meet the ethanol mandate. This cost will likely be somewhat higher than the average cost of production. The per gallon cost of ethanol can be written in equation form as

[4] It is not certain that the wholesale price of E10 will equal the blended price of ethanol and gasoline when oil companies will want to recoup their costs of acquiring RINs. We later change this assumption and assume that the wholesale price of E10 only reflects the wholesale cost of gasoline.

$$Cost = \frac{P_{corn}}{2.75}(1 - 0.95\frac{17}{56}) + OVC$$

where *Pcorn* is the price of corn and *OVC* stands for other variable production cost. A simplifying assumption in this formula is that distillers grains sells for 95 percent of the price of corn. A reasonable value for *OVC* is 50 cents per gallon.[5] Figure 1 shows the resulting relationship between the price of corn and the variable cost of producing ethanol. Each one dollar increase in the price of corn increases production costs by about 26 cents per gallon. It is important to remember that this cost does not include fixed costs, thus the Figure 1 costs do not represent the full cost of producing corn ethanol. When there is excess capacity, as there is with the corn ethanol industry, RIN prices only need to cover variable production costs, because if these costs are covered then it makes financial sense to produce ethanol.

Given the Figure 1 production costs, it is now a straightforward exercise to calculate the RIN price required to generate a sufficiently low ethanol transportation value to induce owners of flex vehicles to use E85. Figure 2 shows the RIN prices that generate equality between E85 and E10 in fuel cost per mile, as well as 10 and 20 percent discounts in fuel costs per mile for different corn prices. The results in Figure 2 assume that E10 is priced as if it were E0 and that wholesale gasoline costs $2.80 per gallon, thus a $3.47 per gallon gasoline retail price. This assumption is made to reflect the fact that oil companies will try to cover the cost of acquiring RINs by passing on these costs to consumers who buy E10.

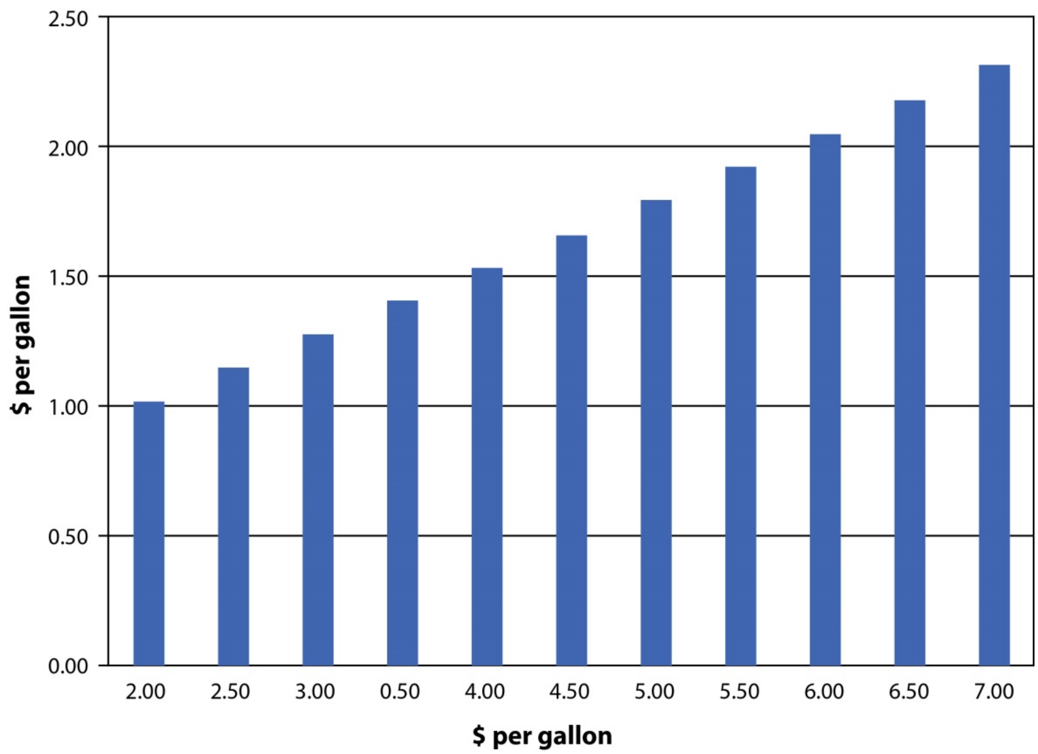

Figure 1. Impact of corn price on ethanol production costs

[5] See for example the variable cost calculations that can be found at http://www.agmrc.org/renewable_energy/ under Ethanol Profitability.

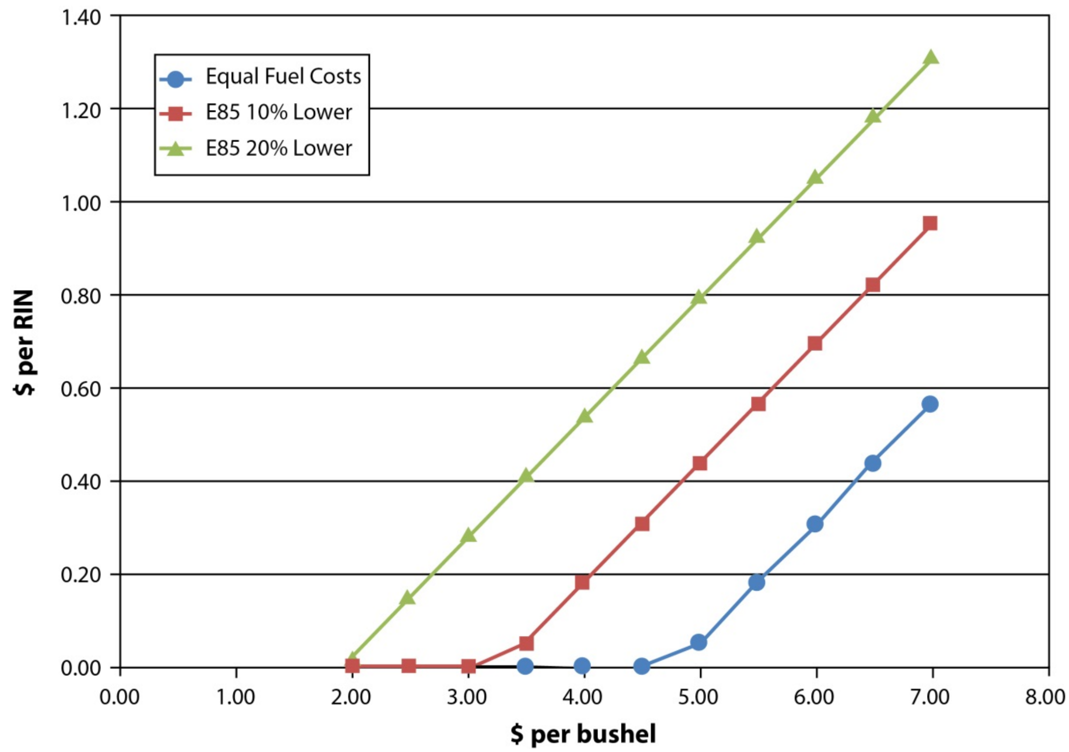

Figure 2. RIN prices required to generate indicated fuel cost savings from E85 for different corn prices

The results in Figure 2 show the importance of the price of corn on required RIN prices. For example, if corn prices drop to $3.00 per bushel, then the transportation value of ethanol that is required to generate a 10 percent reduction in fuel costs would cover the cost of producing ethanol. Thus the required RIN price would be zero. However, with a $5.00 per bushel cost price the required RIN price to generate a 10 percent reduction in fuel costs rises to $0.43 per RIN. Corn prices could rise to about $4.50 per bushel and ethanol plants could still cover their production costs at an ethanol transportation value that equates fuel cost per mile. However, if the required discount in fuel cost is 20 percent, then $4.50 per bushel corn would require a RIN value of $0.67 per RIN.

On July 26, 2013, RINs traded at about $1.00 per RIN. Futures prices for corn indicate that plants should expect to be able to buy corn after September for about $4.50 per bushel. From Figure 2, this suggests that RIN traders expect that E85 must be discounted by much more than 20 percent in order to meet expected EPA mandates.

There are at least three explanations for why RIN prices are so high.[6] The first is that RIN traders are pessimistic about the willingness of owners of existing flex vehicles to find an existing place to buy E85, and that a very large discount is needed to spur sales of E85 and to induce new car buyers to seek out flex fuel cars. The second explanation is that the Figure 2 analysis understates the required RIN prices because it does not account for the increased profit margin that retailers will demand from E85 sales to install an adequate number of E85 pumps. A higher profit margin implies a greater retail

[6] In fact, earlier in July, RIN prices peaked at about $1.40 per RIN, which was equivalent to a 40 percent reduction in fuel cost with $4.50 per bushel corn.

price markup than assumed in Figure 2, which can only be accomplished by lowering the transportation value of ethanol through higher RIN prices. The third explanation is that RIN market participants are not all that informed about what likely RIN prices will be in the future, and that high RIN prices reflects this uncertainty.

Potential Demand for E85

Data from Brazil demonstrates that owners of flex vehicles differ in their proclivity to fill their tank with ethanol instead of gasoline. In a recent study,[7] Pouliot estimated that 20 percent of Brazilian drivers of flex vehicles choose gasoline even when the cost per mile from ethanol was 15 percent lower than gasoline and that 20 percent of flex drivers choose ethanol when ethanol is 10 percent more expensive than gasoline. This implies that to get 80 percent of owners of flex vehicles to choose ethanol requires a 15 percent discount on the cost per mile traveled. If the distribution of attitudes towards ethanol in the United States is similar to those in Brazil, then this empirical finding can be used to look at the discount needed to induce US owners of flex vehicles to fill up with E85. Figure 3 uses the findings of Pouliot to calculate the proportion of drivers who choose E85 assuming that they all have easy access to the fuel.

Based on a database of current vehicle registrations that we acquired, there were approximately 14.6 million registered flex vehicles in the United States as of January 1, 2013.[8] If each of these vehicles use 600 gallons of E85 per year and E85 contains 75 percent ethanol, then this represents 6.6 billion gallons of potential ethanol

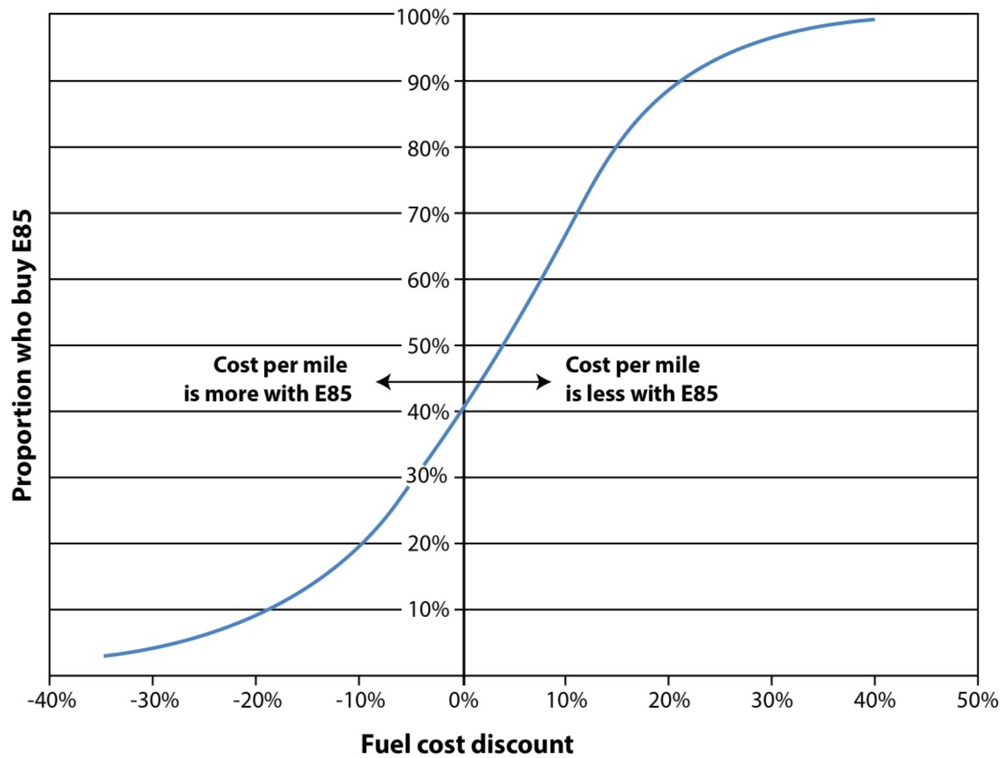

Figure 3. Proportion of flex owners who choose E85
Source: Based on Pouliot.

[7] The working paper is available at: http://ageconsearch.umn.edu/handle/150964.
[8]Registration data of flex vehicles were obtained from Hedges and Company who provided us with the number of registered flex vehicles for each zip code in the United States.

consumption. We can multiply 6.6 billion gallons by the proportion of drivers who would want to use E85 from Figure 3 to determine the demand for E85. Figure 4 graphs the resulting demand curve with the vertical axis showing the ratio of fuel cost per mile traveled from E85 relative to E10, and the horizontal axis showing the resulting consumption of ethanol consumed in E85.

What Figure 4 tells us is that if US drivers had the same access to E85 as Brazilian drivers have to ethanol, and if E85 were priced to equate cost per mile traveled, then about 2.7 billion gallons of ethanol would be consumed as E85. A bit more than five billion gallons would be consumed if E85 were priced to generate a fuel cost savings of 15 percent.

Actual Demand for E85

According to E85prices.com, there are 3,072 retail gasoline stations that sell E85. This may sound like a lot, but extrapolating from the 2007 Economic census, this represents only 2.7 percent of US retail stations. Figure 5 shows the location of these stations as available on E85prices.com. The heaviest concentration of stations selling E85 is in the upper Midwest. Relatively few are located in the major metropolitan areas in the West, on the East Coast, in Texas, or in the Southeast.

Figure 6 shows the location of the registered flex vehicles in the United States. Comparing Figure 5 to Figure 6 reveals an apparent mismatch in most of the country between where the flex vehicles are located and where the E85 stations are located. The exception to this mismatch is the major cities in the Midwest. The mismatch is particularly severe in Texas, the Southeast, and parts of California, which have few E85 stations but many vehicles.

Figure 7 summarizes the mismatch between the location of flex vehicles and the location of stations that sell E85. The distance between the zip code center where flex vehicles are located and the closest station that sells E85 is on the horizontal axis. This distance is an approximation of the distance between the nearest fuel station (assumed to be at the zip code center) and the nearest fuel station that offers E85. It is, in fact, the extra distance that must be driven to access E85 from the fuel station that offers regular gasoline that is the closest to the location of flex vehicles that matters in the E85 purchase decision. That distance is zero if the nearest fuel station offers E85. The total number of flex vehicles that are located closer to a station than the indicated distance is on the vertical axis. For example, about 13.4 million flex vehicles are located in zip codes that have a geographic center that is within 50 miles of an E85 station. Of course, it is not reasonable to expect people to normally drive 50 miles out of their way for fuel, so the more relevant distance range is less than 50 miles. Figure 8 shows the same data but zooms into distances less than 10 miles.

As shown, about 8 million flex vehicles are located in zip codes with a geographic center within 10 miles of a station that sells E85. Being within 10 miles of station at least makes it feasible for an owner of a flex vehicle to find an E85 station if the fuel cost discount is attractive enough. These 8 million vehicles represent a potential demand of about 4 billion gallons of ethanol consumed as E85 if all 8 million vehicles used E85 all the time.

We know from Figure 3, however, that not all owners of flex vehicles will buy E85 unless the discount is quite large. Because it costs time and money to travel to an E85 station, owners that live 10 miles from a station will be less likely to use E85 than an owner that

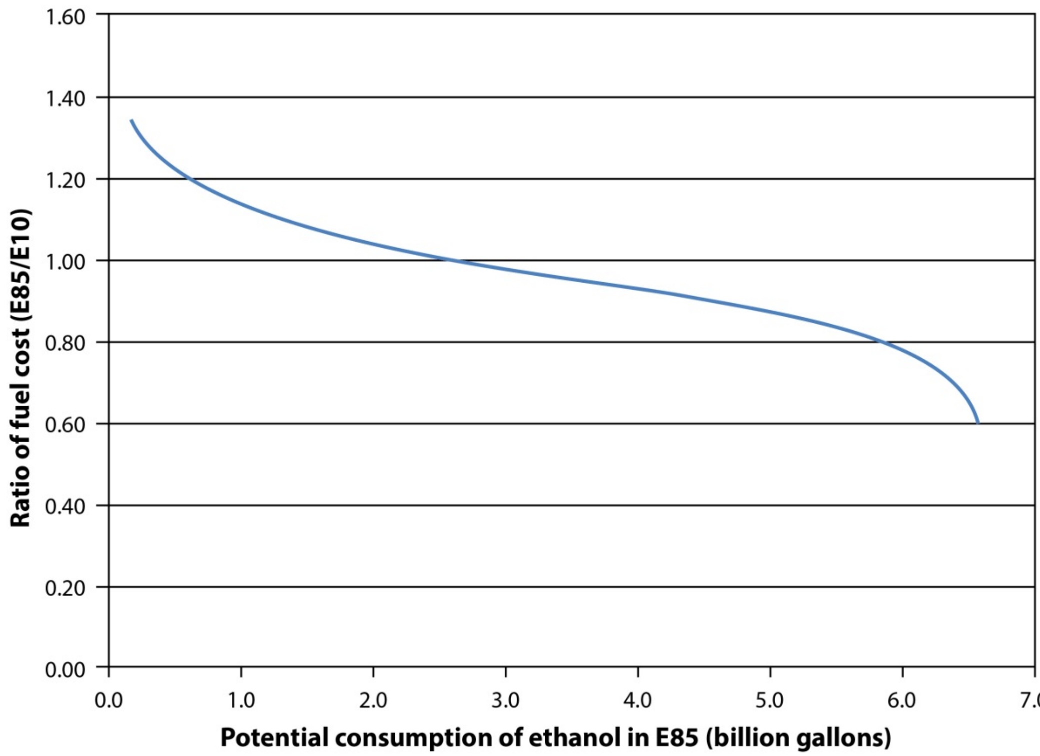

Figure 4. Potential demand for ethanol consumed in E85

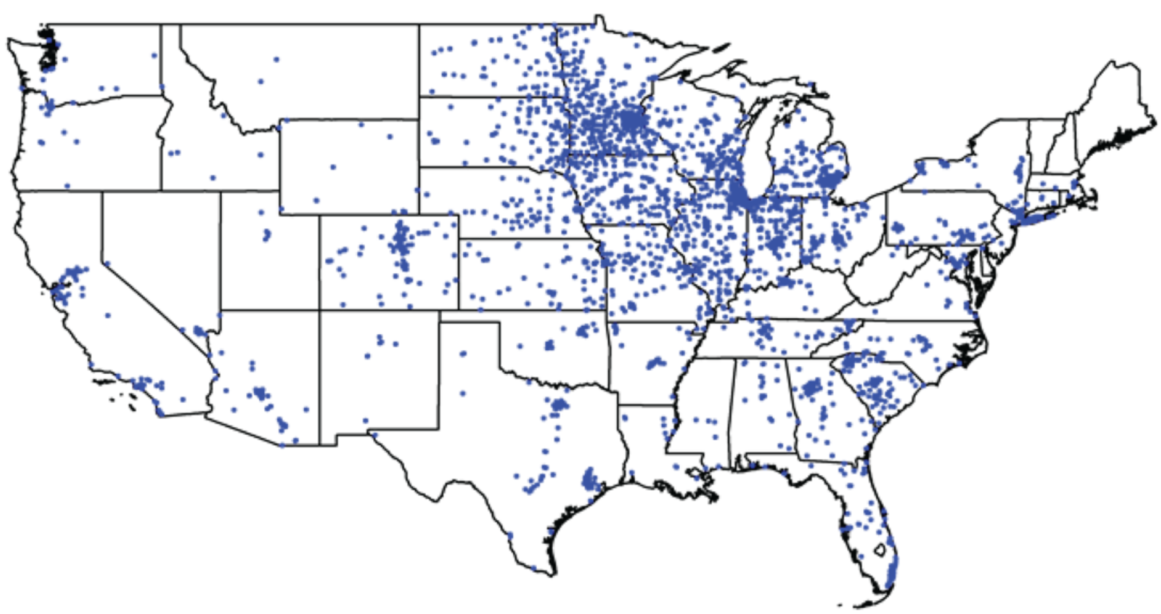

Figure 5. Location of stations selling E85
Source: E85Prices.com

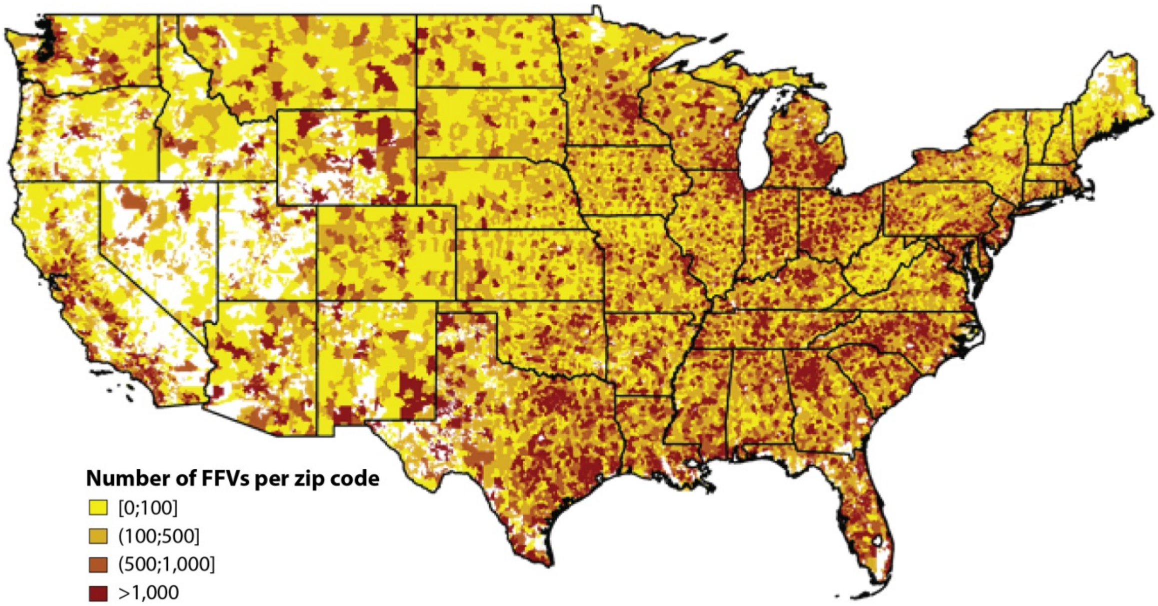

Figure 6. Location of flex vehicles

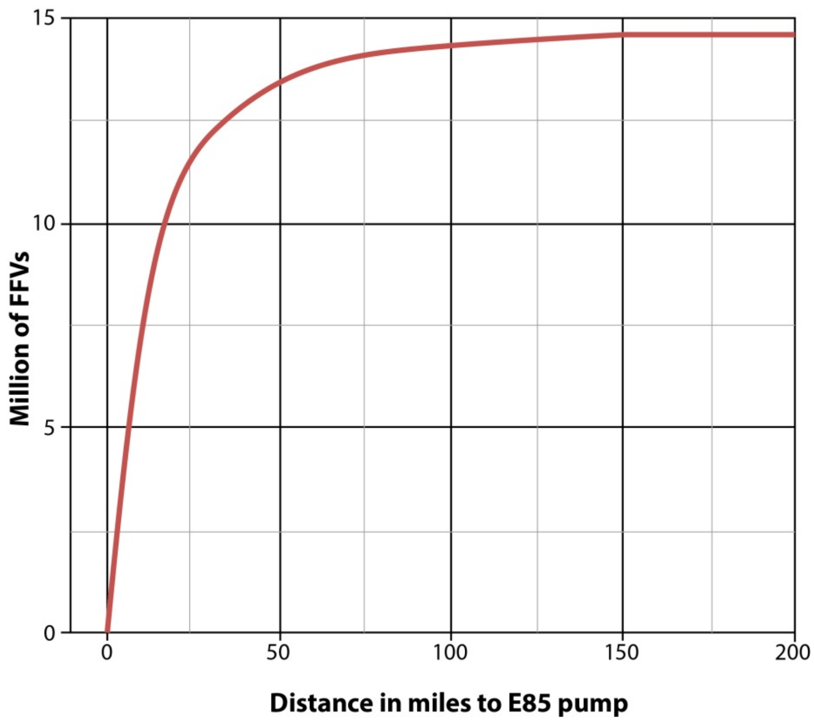

Figure 7. Distribution of distance to E85 station

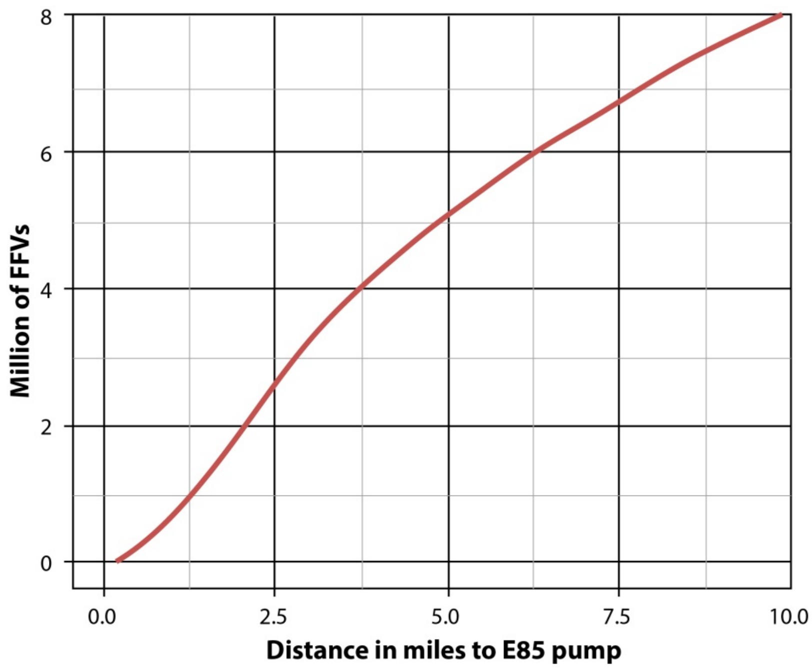

Figure 8. Distribution of distance to E85 Station: 0 to 10 miles

lives right next door. Estimates of the impact of distance on the Figure 3 distribution of willingness to use E85 are beyond the scope of the present paper. For now, we simply assume that an additional 25 percent fuel discount over and above the Figure 3 levels is needed to keep constant the proclivity to buy E85 for owners who live 10 miles away from an E85 station. For illustration purposes we assume that this additional fuel cost discount decreases linearly with distance so that flex vehicle owners who live five miles from an E85 station will require an additional fuel discount of 12.5 percent. The results of adding this discount on the proportion of drivers who buy E85 are shown in Figure 9. At a zero distance, the proportion who fill up with E85 for a given fuel discount level is the same as in Figure 3. Increasing distance reduces the proportion willing to buy E85 given a certain fuel cost discount. To keep the proportion constant requires an increase in the fuel cost discount as shown.

The Figure 9 curves now allow calculation of the demand curve for ethanol consumed as E85. For each zip code the proportion of flex vehicles that choose E85 is calculated for different fuel cost ratios. These proportions are then multiplied by the number of vehicles that are located in each zip code and then by 500, which is the average number of gallons of ethanol assumed to be consumed per year for the average driver that fills up on E85 all the time. The results are shown in Figure 10. Two curves are shown: the lower curve assumes that only flex vehicles located within 10 miles of an E85 station will use ethanol, and the upper curve makes the calculations for all US zip codes.

Concentrating on the 10-mile curve, the results indicate that about one billion gallons of ethanol could be consumed if E85 were priced to generate a six percent reduction in fuel costs. If the price were lowered further to generate a 15 percent reduction then about two billion gallons could be consumed. A 30 percent reduction would be needed to induce three billion gallons of consumption.

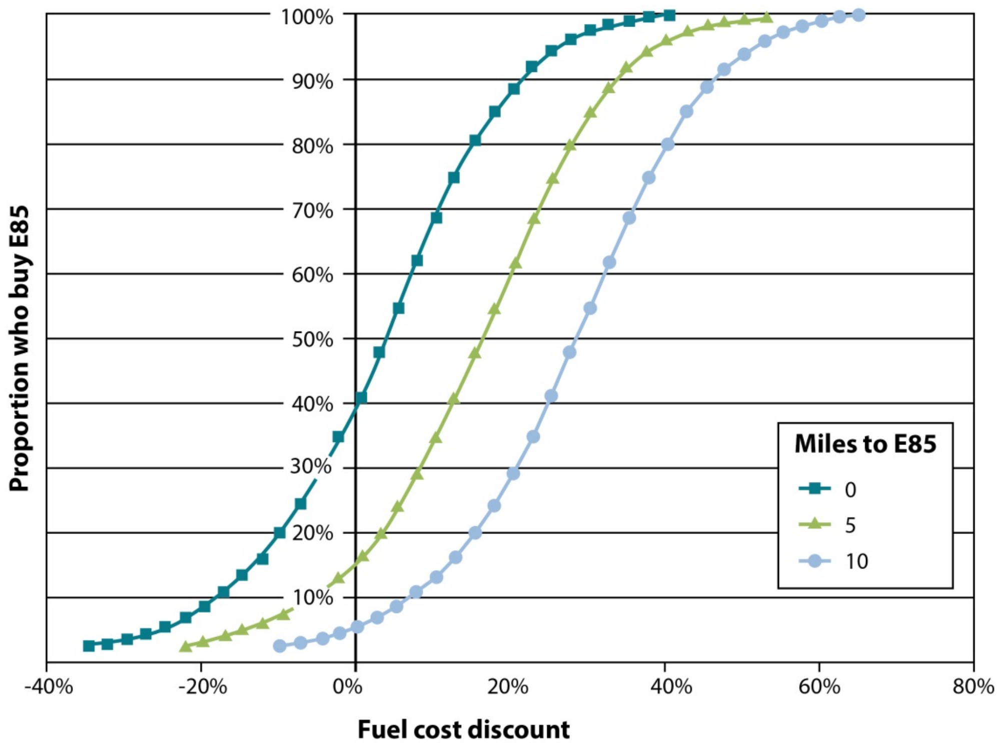

Figure 9. Distance-adjusted proclivity to buy E85

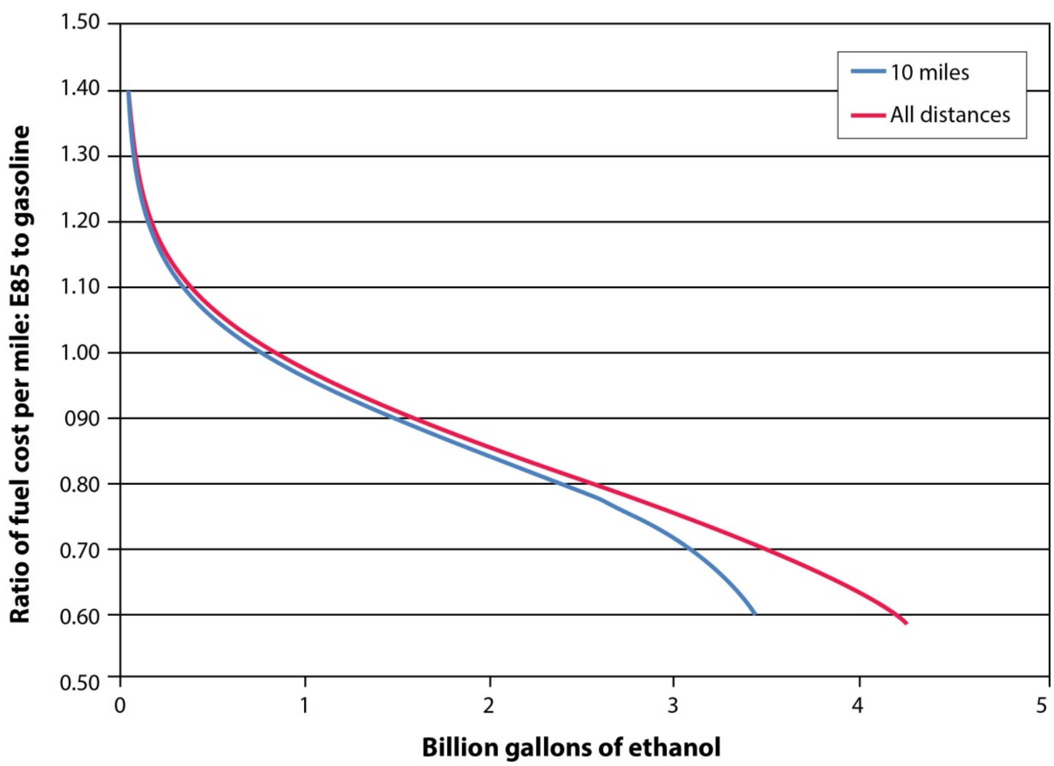

Figure 10. Demand for ethanol from E85

Before concluding this section, some words of caution are in order. As with any set of calculations, the results presented here are only as valid as the assumptions on which they are based. Because E85 has not been historically priced to generate fuel cost savings, we do not have data to measure US drivers' willingness to buy E85 when its price is discounted relative to gasoline. Hence we have relied on data generated by Brazilian drivers. We also have no data on which to base the additional fuel cost savings that would be needed to induce owners of flex vehicles who live some distance from an E85 station to fill up at that station. The results in Figure 10 illustrate the demand for ethanol if that additional fuel savings is 25 percent for owners who live 10 miles away. We also assume that existing E85 stations can obtain enough E85 and will install enough pumps to fill the demand by owners of flex vehicles. Clearly some investment in additional pumps at existing stations would be needed to meet the demand if E85 is heavily discounted. We also have no data about the actual location of the flex vehicles within a zip code. For this analysis, we simply assumed that all are located right at the geographic center of the zip code. If an E85 station happens to be located right in the center of a zip code also, then we assume that the distance for all flex vehicles in that zip code is zero and no additional discount is needed to hold constant the proclivity to buy E85 that is shown in Figure 3. Given all these caveats, it is still worthwhile to use the Figure 10 demand curve to look at different ethanol mandate levels to determine what RIN prices will need to be in 2014 and 2015.

RIN Prices Needed to Meet 2014 and 2015 Ethanol Mandates

There are two mandates that may be met by ethanol in 2014 and 2015. The conventional biofuel mandate in these two years is 14.4 and 15 billion gallons. The portion of the advanced mandate that is not met by biodiesel may also be met by imported sugarcane ethanol. The advanced mandate is scheduled to increase from 3.75 billion gallons in 2014 to 5.5 billion gallons in 2015. Of this 1.75 billion gallon increase, 1.25 billion gallons are accounted for by an increase in the cellulosic biofuel mandate from 1.75 to 3.0 billion gallons. The other 500 million gallons is accounted for by an increase in other advanced biofuels.

There exists great uncertainty regarding what EPA will propose regarding the total volume of advanced biofuel and whether EPA will mandate an increase in the biomass-based diesel mandate. It seems likely that EPA will not propose less than 830 million gallons of advanced biofuel that is not biodiesel in either 2014 or 2015. After all, that is the volume they proposed for 2013. It also seems unlikely that EPA will maintain the scheduled increases in the total advanced mandate because most of the increase is caused by cellulosic biofuels that will not materialize on the market in large quantities in the next two years. For illustration purposes, we assume here that the upper limit on the advanced biofuel mandate that may be met by ethanol is 1.5 billion gallons in 2014 and 2.0 billion gallons in 2015. This represents a significant increase from current volumes. The resulting ethanol volumes are found by adding together the conventional biofuels volumes with the assumed upper and lower limits on advanced ethanol volumes are given in Table 2.

Table 2. Range of Ethanol Volumes that May Need to Be Consumed in 2014 and 2015

	2014	2015
	(billion gallons)	
Conventional Biofuel	14.40	15.00
Advanced Biofuel		
Lower Limit*	0.83	0.83
Upper Limit*	1.50	2.00
Total Ethanol		
Lower Limit	15.23	15.83
Upper Limit	15.90	17.00
Ethanol Beyond E10		
Lower Limit	2.23	2.83
Upper Limit	2.90	4.00

*These are assumed values pending release of EPA's draft rule for 2014.

The required E85 fuel cost discounts to achieve these different volumes can be obtained from the data that was used to generate the ethanol demand curve in Figure 10, and are shown in Figure 11. In 2014, the required fuel cost discounts range from 17 to 24 percent. In 2015, they range from 23 to 40 percent. With a wholesale gasoline price of $2.80 per gallon and an associated E10 price of $3.49 per gallon, the pump prices for E85 that generate these fuel cost savings range from $2.24 per gallon for the 17 percent savings to $1.65 per gallon for the 40 percent savings.

It is straightforward to calculate what the transportation value of ethanol must be in order to generate these E85 pump prices. These are shown in Figure 12 for three wholesale gasoline prices. Higher gasoline prices increase the transportation value of ethanol in E85, which results in the required fuel costs savings. As shown, 40 percent fuel cost savings can only be achieved at very low transportation values for ethanol. With a wholesale price of gasoline at $2.80 per gallon, the transportation value of ethanol must be only 25 cents per gallon.[9]

The last step is to subtract the Figure 12 ethanol transportation values from ethanol production costs to obtain the RIN prices that will be needed in 2014 and 2015 to induce these fuel cost savings. The intrepid reader who has stayed with this paper this long knows that RIN prices vary with many factors including the volume of ethanol needed to meet mandates, the price of corn, and the price of gasoline. Thus results are presented for three corn prices, three gasoline prices, and the four ethanol volumes that are shown in Figures 11 and 12.

Not to add to complexity, but for completeness, there are actually two ethanol RIN prices that we need to be concerned with: conventional biofuel RINs (D6 RINs) and advanced biofuel RINs (D5 RINs). The price for conventional biofuel RINs equals the difference in corn ethanol production costs and the transportation value of ethanol. The price of advanced biofuel RINs equals the difference between the cost of importing sugarcane ethanol from Brazil minus the ethanol transportation values shown in Figure 12.

Figure 13 provides RIN prices for the four different ethanol volumes and three different corn prices. The wholesale gasoline price in Figure 13 is set at $2.80 per gallon. Figure 14 and 15 show the effect on RIN prices from higher and lower gasoline prices. RIN prices for advanced biofuels (D5) are shown in Figure 16 for alternative gasoline prices assuming that imported sugarcane ethanol is used to meet the advanced mandate.[10]

[9] The very low transportation values shown in Figure 11 are low in part because the wholesale to retail markup for fuel used here is approximately constant at 75 cents per gallon. If the markup were proportionate, then the transportation values would be higher than those shown in Figure 12.
[10] Other assumptions behind Figure 16 are that the price of sugarcane ethanol landed in the United States is $2.28 per gallon with an exchange rate of 2.27 Brazilian reais per US dollar.

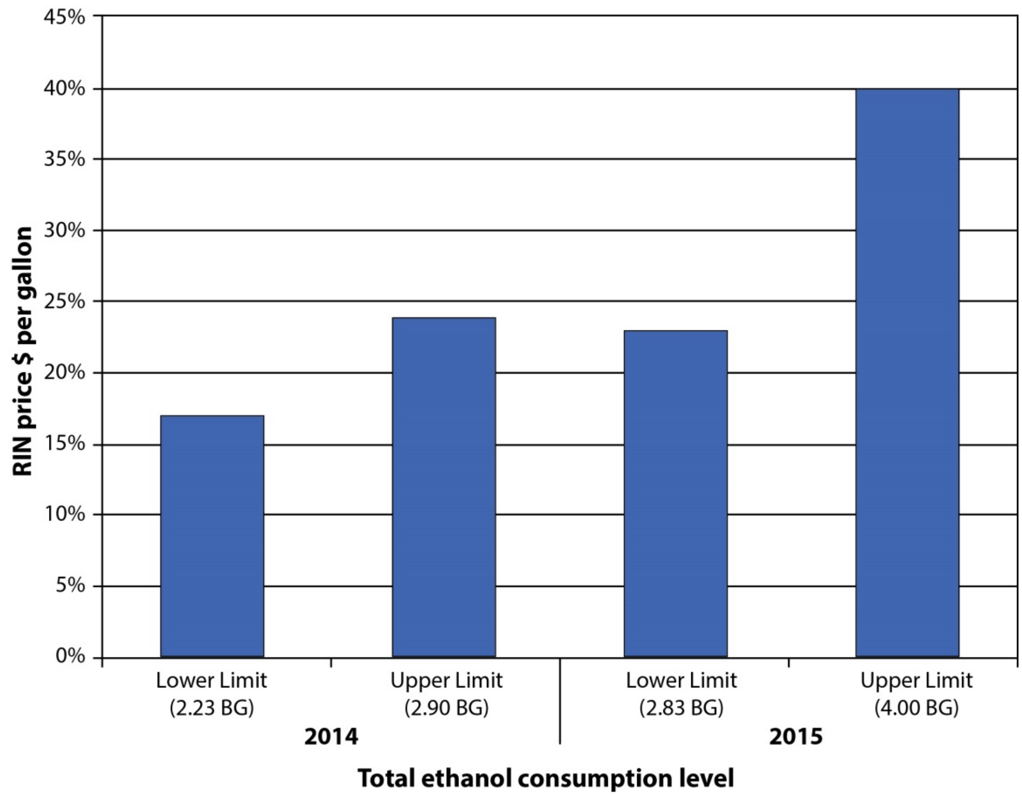

Figure 11. Fuel cost discounts needed to induce indicated volumes of E85 ethanol consumption

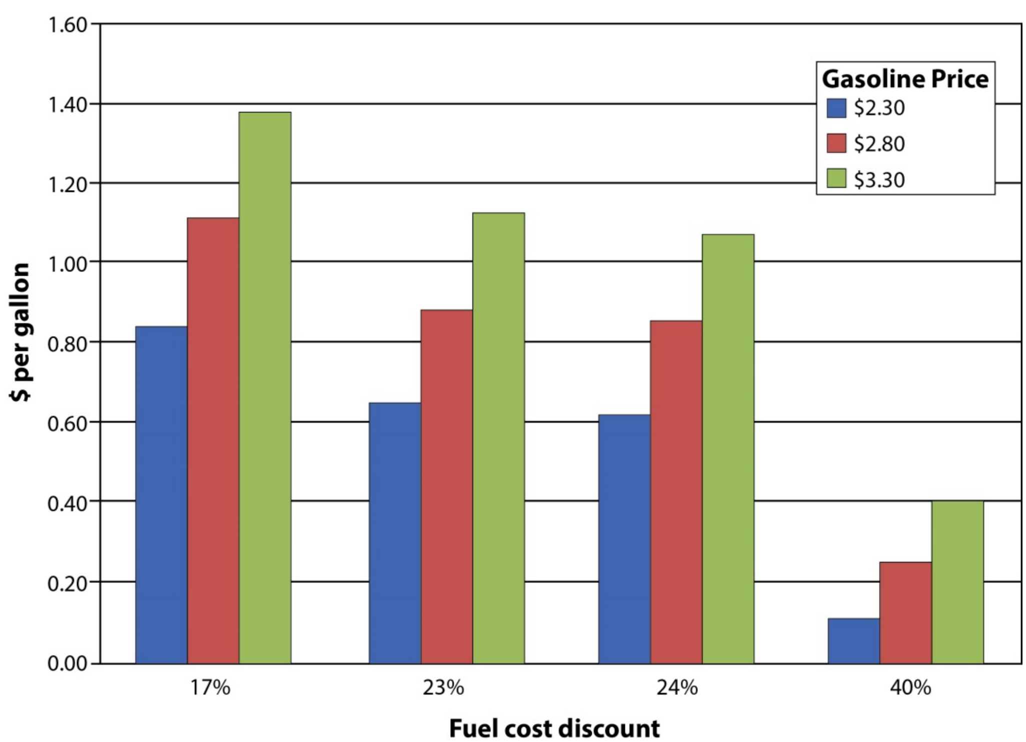

Figure 12. Ethanol transportation values required to meet mandates with E85

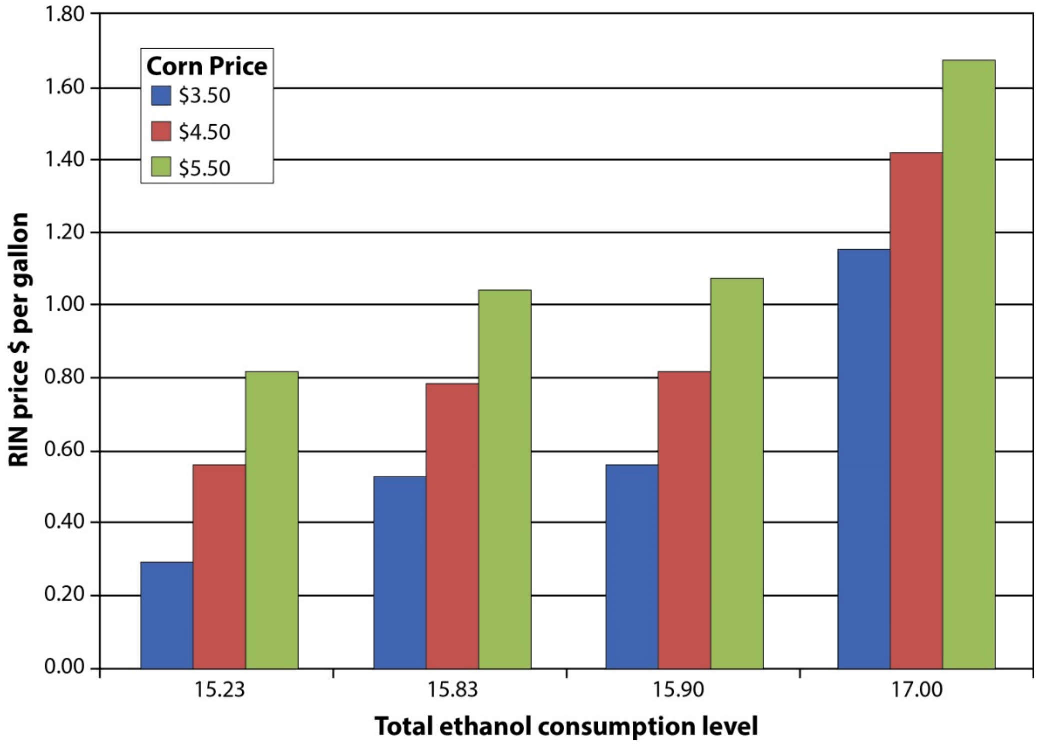

Figure 13. RIN prices required to induce indicated level of ethanol consumption with $2.80 per gallon gasoline and alternative corn prices

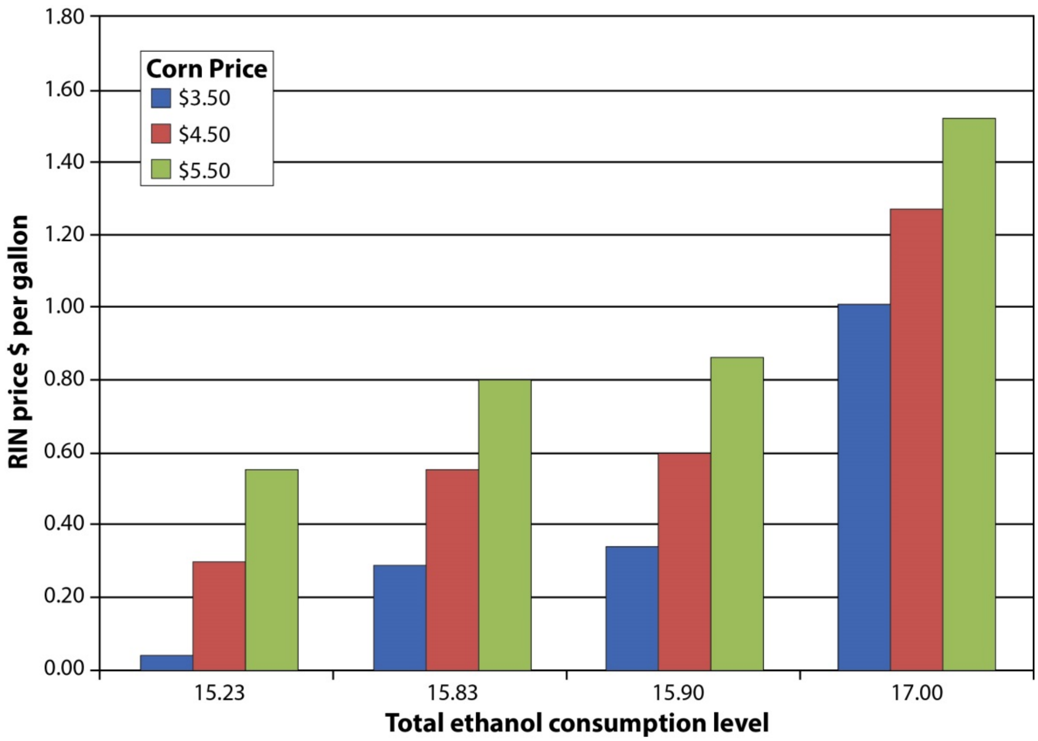

Figure 14. RIN prices required to induce indicated level of ethanol consumption with $3.30 per gallon gasoline and alternative corn prices

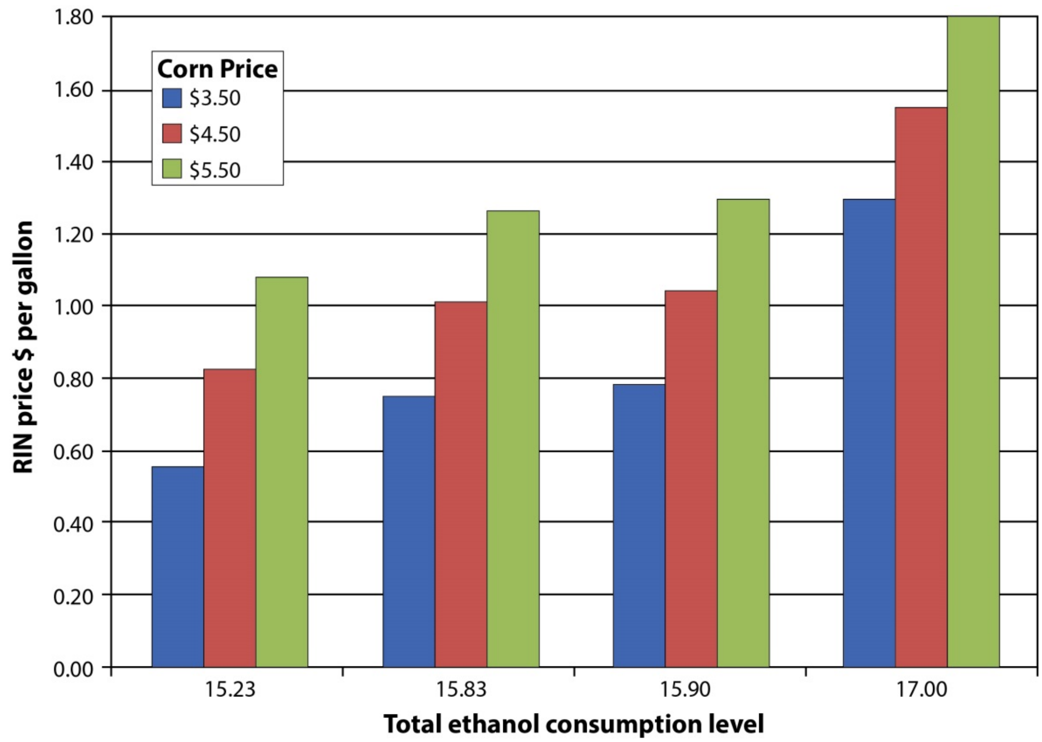

Figure 15. RIN prices required to induce indicated level of ethanol consumption with $2.30 per gallon gasoline and alternative corn prices

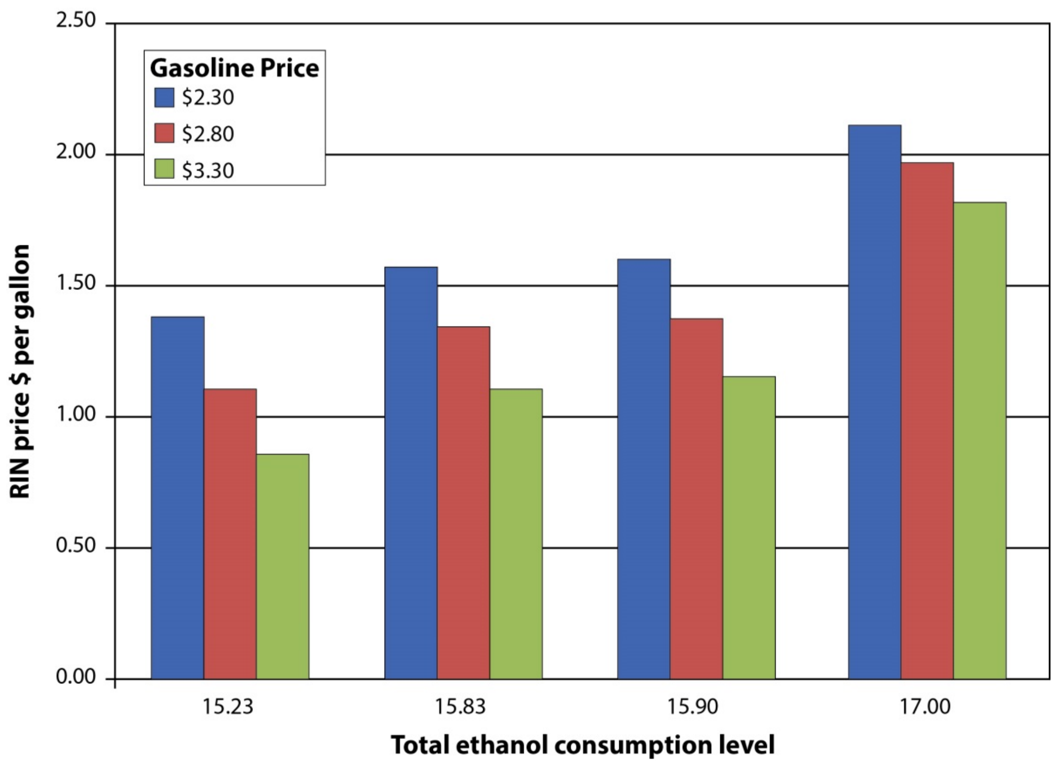

Figure 16. RIN Prices for Imported Sugarcane Ethanol

Current futures prices indicate that gasoline prices will be around $2.80 per gallon and that ethanol plants will pay around $4.50 per bushel for corn in 2014. The results in Figure 13 show that at these prices conventional biofuel RIN prices could vary from a low of less than 60 cents per gallon to a high of $1.40 per gallon depending on the volume of biofuels that EPA mandates. Current D6 RIN prices of around $1.00 per gallon are consistent with current futures prices if EPA mandates more than about 16 billion gallons in 2015 and beyond. If EPA holds ethanol mandates below 16 billion gallons, then then demand for E85 will be enough to maintain RIN prices at significantly less than $1.00 per gallon. [11]

Of course, nobody knows what the future holds for gasoline and corn prices. Higher gasoline prices will lead to significantly lower RIN prices, except at the 17 billion gallon mandate level, as shown by Figure 14. Furthermore, the current high RIN prices are consistent with lower gasoline prices even at rather modest mandate levels as shown in Figure 15. The impact of a change in corn price on RIN prices is constant across the different scenarios considered. For each $1.00 increase in corn prices, RIN prices increase by 26 cents per gallon.

Figure 16 shows that RIN prices for imported sugarcane ethanol should be significantly higher than for corn ethanol prices. The reason for a higher RIN price is that the demand for ethanol in Brazil is strong and transportation costs of bringing in Brazilian ethanol must be also covered. The high RIN prices for sugarcane ethanol shown in Figure 16 raise the likelihood that sugarcane ethanol will not meet all of the advanced mandate not accounted for by the biomass-based diesel mandate. Rather, some portion of it will be met by biodiesel. If this occurs, then the amount of ethanol consumption that will be required in 2014 and 2015 will be lower than assumed here. This will cause RIN prices for both conventional and advanced biofuels to decrease somewhat because the transportation value of ethanol will not have to be so heavily discounted.

Policy Implications

Over the last six months many have commented on the need to modify the RFS because of the difficulty with expanding US ethanol consumption beyond about 13 billion gallons. For example, in a recent op-ed, Jason Bordoff, Director of Columbia University's Center on Global Energy Policy, opined that we should revise our mandates by staying behind the blend wall because of the high cost of RINs and the paucity of stations that sell E85.[12] Similarly Scott Irwin and Darrel Good from the University of Illinois advocate “freezing” the mandates just “over” the blend wall because of the uncertainty associated with consumer demand for higher-than-E10 blends.[13] Some in the oil industry also claim that it will be impossible to move beyond the blend wall so their only choice will be to reduce gasoline sales in the United States, thereby driving up consumer prices.

It is not surprising that many believe that E85 sales cannot move ethanol consumption significantly past the blend wall. After all, total sales of E85 have barely topped 100 million gallons when required volumes to move beyond the blend wall involve billions of gallons. Though E85 rarely, if ever, has been priced at a level where it saves consumers

[11] Of course, if traders believe that ethanol consumption must expand significantly past 16 billion gallons in 2016 and beyond, then current RIN prices may in fact be too low to create a large enough incentive for consumers to buy flex vehicles and gasoline station owners to invest in E85 capabilities.

[12] See Bordoff, J. “Well intentioned but flawed, U.S. biofuel policy in need of change**.”** July 24, 2013. Available at http://mobile.reuters.com/article/idUSBRE96P13N20130726?irpc=932

[13] Irwin, S., and D. Good. “Freeze It - A Proposal for Implementing RFS2 through 2015.” April 10, 2013. Available at http://farmdocdaily.illinois.edu/2013/04/freeze-it-proposal-implementing-RFS2.html.

money. Why would owners of flex vehicles buy a fuel that increases their fuel costs? Typically E85 has been priced at a level that increases fuel cost by 10 to 20 percent. As shown in our demand curve in Figure 10, low levels of E85 consumption should be expected when E85 is not priced to save consumers money.

Significant barriers do exist to expand ethanol consumption with E85. Besides the price issue, the foremost barrier is that a large proportion of the flex vehicle fleet is located in places where E85 is not available. Even so, the analysis presented here shows that enough flex vehicles are located close enough to stations that sell E85 that significant volumes of E85 would be sold if it were appropriately priced. When gasoline is selling at $3.50 per gallon, $2.00 per gallon E85 would attract quite a lot of attention.

Note that this analysis uses the number of flex vehicles as of January 2013. It is not unreasonable to forecast an increase in the number of flex fuel vehicles of more than one million per year over the next couple of years. If true, and if a significant number of those new vehicles are located near E85 pumps, our analysis underestimates the potential demand for E85. The implication is that RIN prices could be lower than those presented in this analysis, provided the caveat, again, that fuel stations can offer the volumes of E85 implied by the mandates.

If the United States is serious about expanding the use of biofuels to replace gasoline, then there are two ways to go about it. The economist's first choice is to tax gasoline but not biofuels, through a carbon tax for example. However, given the lack of appetite for a carbon tax or a large increase in the gas tax, the current policy of a mandate implemented with a tradable permit strategy will create incentives for consumers, retailers, and oil companies to expand use of biofuels in the least cost manner. It seems that ethanol is the least-cost fuel available. It remains to be seen what the costs associated with creating the infrastructure to greatly expand E85 consumption will be. Current high RIN prices create a large incentive for oil companies to increase consumption of E85 because expansion in E85 consumption will decrease RIN prices, and any reduction in RIN prices saves them significant amounts of money. It is likely less expensive for oil companies to subsidize expansion of E85 consumption by strategic subsidies for pumps in Texas and in other parts of the Southeast where there exist lots of flex vehicles and few E85 stations, than it is for them to continue to pay high RIN prices.

The results presented here show that pricing E85 low enough to generate fuel cost savings has the potential to quickly increase ethanol consumption, perhaps by three billion gallons over the next year or two. If this pricing actually happens then the demand for flex cars will increase as will the willingness of station owners to invest in new tanks and pumps. That is, the response to the low E85 prices will automatically increase the future demand for E85 thereby allowing for expanded ethanol consumption from cellulosic or other low-carbon sources of biofuels. However, this expanded ability to use ethanol will not occur under existing policies unless EPA increases mandates significantly above the E10 blend wall because high RIN prices is the only current policy tool that provides the necessary incentives to increase the distribution capacity and demand for E85.