Peeking Over the Blendwall

An Analysis of the Proposed 2017 Renewable Volume Obligations

PREPARED FOR

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America's Ethanol Supporters

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Executive Summary

In May 2016, the Environmental Protection Agency (EPA) proposed Renewable Volume Obligations (RVOs) for calendar year 2017 under the Renewable Fuel Standards (RFS) program. EPA set the total renewable fuel target under the assumption that nearly all gasoline would be blended with ethanol up to 10 percent by volume (E10) and that approximately 200 - 300 million gallons of motor fuel sold would be gasoline blended with 51 - 83 percent ethanol (E85) which can only be used in flex-fuel vehicles (FFVs). There currently are about 19.6 million FFVs in the U.S. vehicle fleet, which is expected to grow to almost 21 million in 2017; and about 3,100 stations that dispense E85, concentrated primarily in the Midwest, with EPA estimating a mid-point projection of 3,700 such stations in 2017. Because E85 has less energy content per gallon than E10, most FFV drivers will use E85 only when it is priced at a discount to E10. The RFS program includes a price mechanism for valuing and trading "renewable identification numbers" (RINs) that signify a gallon of ethanol blended into fuel; the value of such RINs associated with blending E85 for retail sale can provide an additional subsidy to expand this E85 price discount relative to the E10 price.

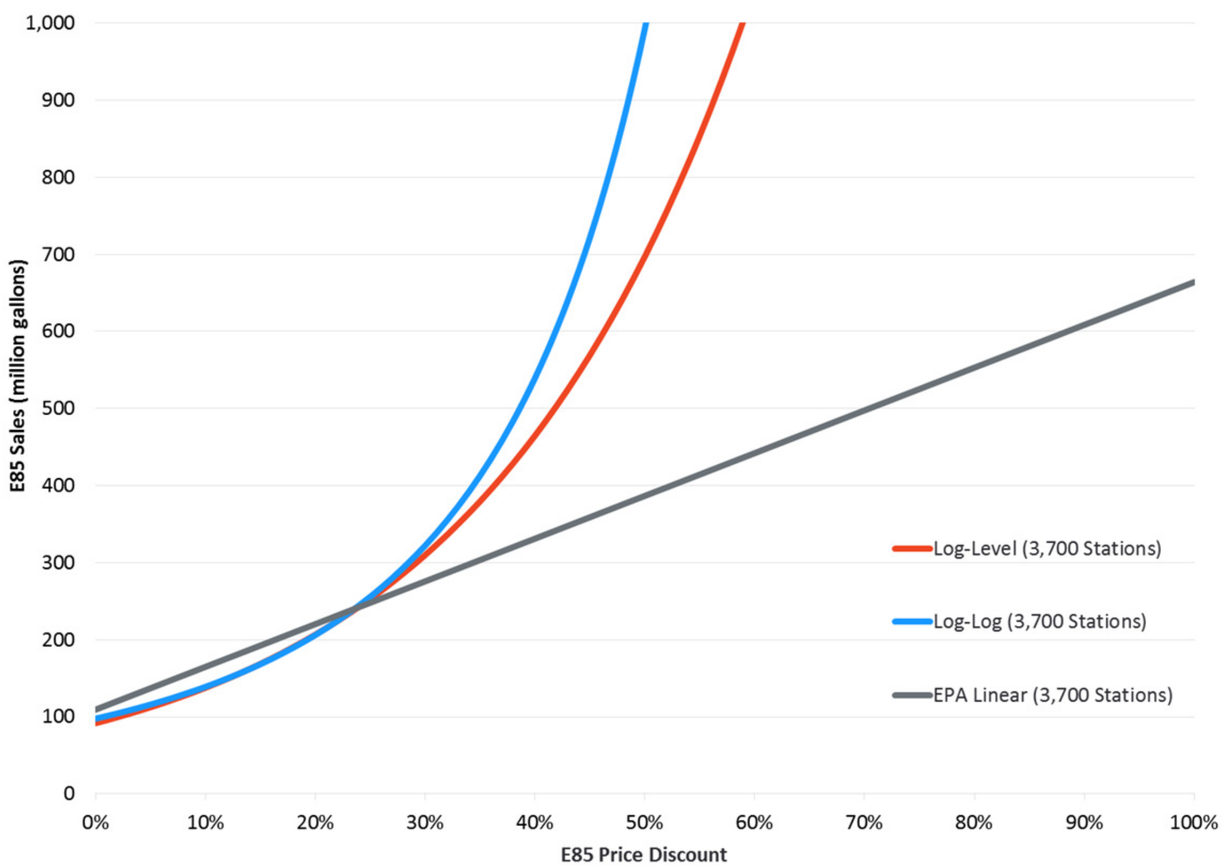
When the RVO implies an average concentration of ethanol in gasoline that exceeds the typical 10 percent level, the so-called "E10 blendwall" is breached. That is, additional volumes of E85 (or potentially blends such as E15 or E30) must be sold in order to displace E10 in the fuel market. For the past several years, EPA has set the RVO under the assumption that E10 would be ubiquitous and that E85 sales would be similar to levels previously observed; that is, they have avoided exceeding the blendwall with substantially expanded volumes of E85. EPA justifies this reluctance to significantly exceed the blendwall by relying on analysis that shows limited pass-through of RIN value to retail E85 prices and limited consumer response to subsequent E85 price discounts. Because EPA considers these market phenomena to reflect constraints, they set RVOs with such limits in mind, and the RVO for 2017 appears to reflect E85 volumes in the 200 – 300 million gallon per year range.

However, EPA's empirical analyses utilize data that reflects market conditions as they existed historically without aggressive RVO targets, providing a "rearview mirror" perspective on the future market. We re-examine these analyses using more appropriate methodologies and more informative data. We find that EPA understates the likely market responses in both areas: we estimate a higher portion of RIN value pass-through to retail prices and project a much more pronounced consumer response to E85 price discounts near the levels where the cost per unit of energy is approximately the same (the energy parity price).

Regarding the relationship between E85 prices and volumes sold, we find empirical evidence for a non-linear relationship – as economic theory and common sense would suggest – and estimate two functional forms that relate E85 discounts (relative to E10 prices) to annual volumes sold (gallons of E85 per station). When we scale the resulting relationships to 3,700 stations nationwide for 2017, we are able to project E85 sales volumes as a function of E85 price discount.

Figure ES-1 shows the non-linear relationships we estimated, along with the EPA linear relationship. Notably, the EPA linear relationship implies that if E85 were offered at a zero market price (*i.e.,* given away for free), the resulting E85 volumes sold would only be about 660 million gallons in 2017, an implausibly low figure.

Figure ES-1: Nationwide E85 Sales as a Function of E85 Price Discount in 2017 (3,700 Stations)



In addition to our analysis of FFV consumer responsiveness to E85 retail price discounts, we also analyze the degree to which blenders and retailers pass through the RIN value down to pump prices of E85. We find evidence that blenders currently pass through as much as 65% of the RIN value downstream, with higher pass-through rates likely in a more competitive market characterized by significant E85 volumes driven by RVOs set beyond the E10 blendwall. We represent these conditions by adopting a 75% pass-through parameter. With these improvements, we estimate RIN prices necessary to drive substantially greater volumes of E85, as shown in Figure ES-2, which assumes that 3,700 E85 stations operate in 2017. Figure ES-2 also includes the corresponding EPA relationship using their assumptions.

Figure ES-2: 2017 RIN Prices and E85 Sales (3,700 Stations)

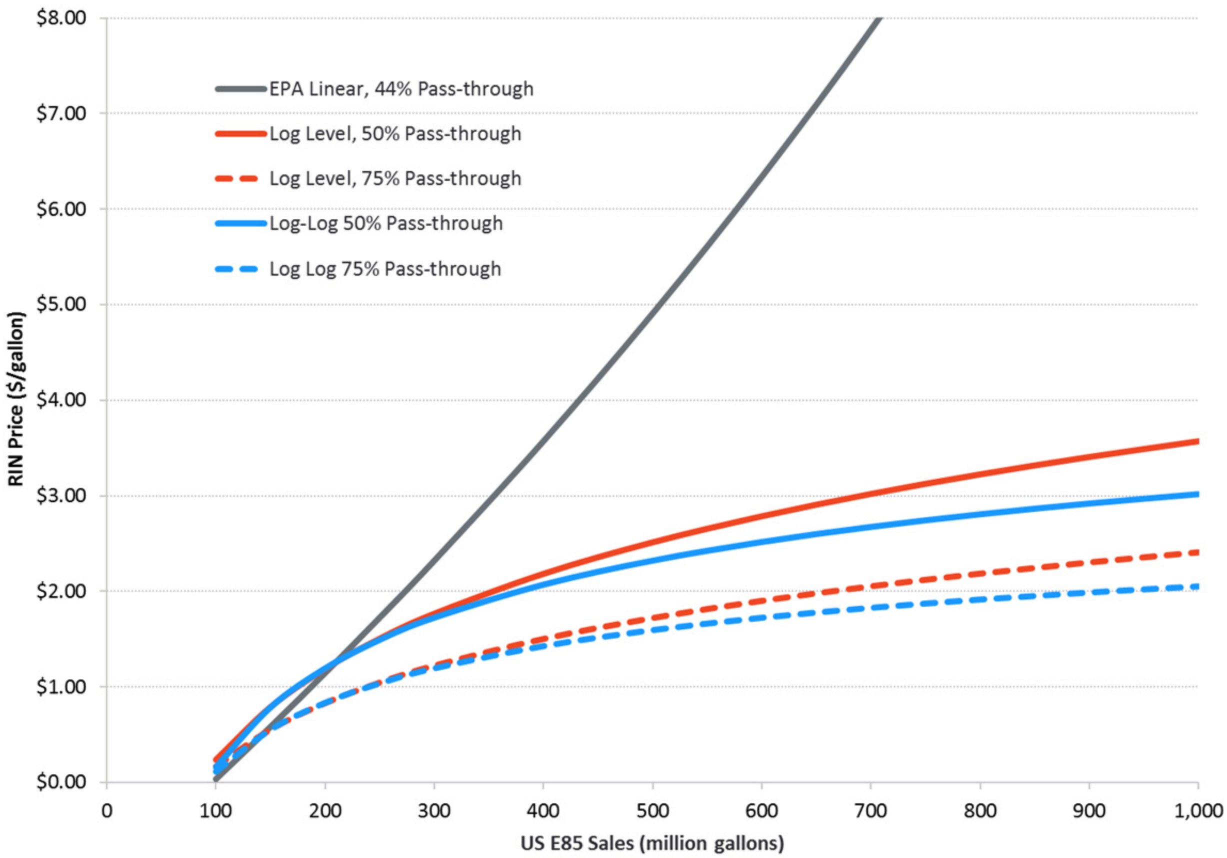
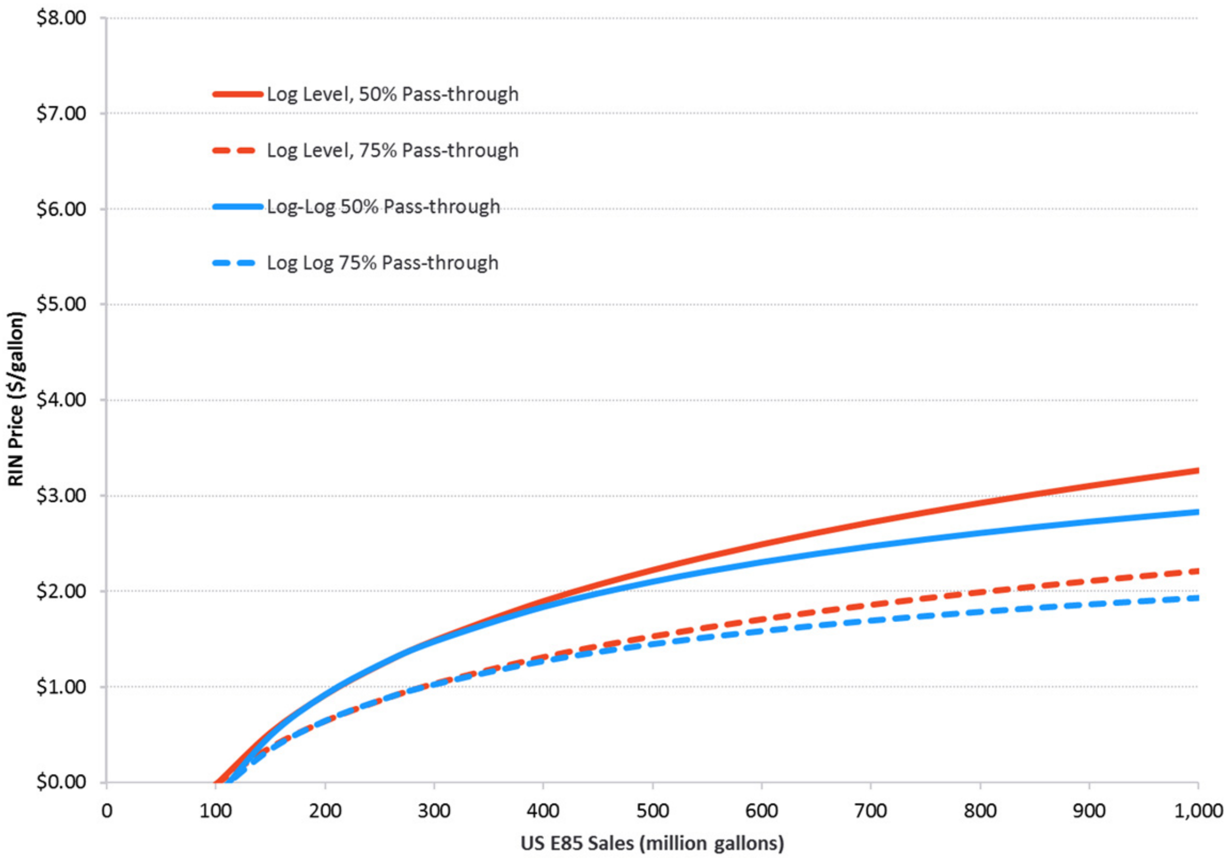


Figure ES-2 illustrates the level of E85 consumption predicted by our model at various RIN prices, using (1) two slightly different functional forms to describe the relationship between the E85 retail price discount (relative to E10 price) and the E85 volumes sold, (log-level and log-log); and (2) two assumed levels of the percentage of the RIN value that is passed through from blenders to retail prices. Figure ES-3 shows the same relationships assuming 4,500 retail E85 stations nationwide operate in 2017. These results show lower RIN prices at every level of E85 sales, as greater station availability drives additional volumes under a methodology based on estimating gallons of E85 sold per station.

Figure ES-3: 2017 RIN Prices and E85 Sales (4,500 Stations)



Overall, our analysis shows that the "constraints" that EPA associates with the RIN pricing mechanism for stimulating increased E85 sales (and relies upon in their justification for the 2017 RVO) are themselves a product of a backward-looking approach, which assumes that historic market outcomes and pricing relationships reflect actual limits on sales. Instead, we provide a peek over the blendwall by describing the price dynamics and consumer reactions that would accompany a transition to an E85 market and RVO well beyond the blendwall. We believe that a new long-run equilibrium would emerge with minimal disruptive effects on fuel prices and much higher use of E85 in existing FFVs.

I. Introduction

A. The Proposed 2017 Renewable Fuel Volume Requirements

In May 2016, the Environmental Protection Agency (EPA) proposed setting the 2017 Renewable Volume Obligation (RVO) for total renewable fuels under the Renewable Fuel Standard (RFS) at 18.8 billion gallons, a reduction of 5.2 billion gallons from the 24.0 billion gallons mandated by legislation.[1] The reduction accounts for a 5.0 billion gallon reduction in cellulosic fuel and a 0.2 billion gallon reduction in non-advanced renewable fuel. The EPA found that the RVO must be reduced due to an "inadequate domestic supply" of renewable fuels, including ethanol, accounting for constraints on distributing and consuming transportation fuels with increasing levels of ethanol in the mix.[2]

The EPA approach for setting the total renewable fuel volume requirement seeks to determine "the maximum supply that can reasonably be expected to be produced and consumed by a market that is responsive to the RFS standards."[3] EPA further clarifies that they are not seeking to set mandates based on the "absolute maximum domestic supply" that could be available under conditions the EPA deems to be ideal, unrealistic, or unlikely to occur.[4] Instead, their approach is to set standards that increase the volume of renewable fuels consumed as transportation fuel, that take into account the ability of the market to respond to RVOs, and that represent the "maximum that is reasonably achievable given the various constraints on supply" (as EPA interprets the term).[5]

Ethanol is the most common renewable fuel used to generate additional Renewable Identification Number credits (RINs) to satisfy the RFS requirements.[6] EPA says that additional ethanol supply is not limited by domestic production and import capacity, but instead by the following constraints:[7]

1. "Overall gasoline demand and the volume of ethanol that can be blended into gasoline as E10 (the so-called E10 blendwall).

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1 Renewable Fuel Standard Program: Standards for 2017 and Biomass-Based Diesel Volume for 2018; Proposed Rule, 81 Fed. Reg. 34,777 (May 31, 2016; 40 CFR 80) - 81 FR 34,777.

2 81 FR 34,786.

3 81 FR 34,781-82.

4 81 FR 34,788.

5 *Ibid.*

6 81 FR 34,789

7 81 FR 34,790.

2. The number of retail stations that offer higher ethanol blends such as E15 and E85.
3. The number of vehicles that can both legally and practically consume E15 and/or E85.
4. Relative pricing of E15 and E85 versus E10 and the ability of RINs to affect this relative pricing.
5. The demand for gasoline without ethanol (E0)."[8]

EPA projects the volume of ethanol to be sold in E10 to be 14.18 billion gallons, based on the EIA's projected demand for gasoline in 2017 and the assumption that all gasoline will include 10% ethanol except for a limited volume of E0 sold to recreational vehicles.[9] The projected ethanol sold in E10 accounts for the constraint created by total E10 demand (constraint 1 from the list above) and the constraint created by E0 demand (constraint 5). EPA proposes that an additional 220 million gallons of ethanol are likely to be sold through E15 and E85 fuel sales for a total of 14.4 billion gallons of ethanol, which EPA notes is an increase from their previous estimate of 200 million gallons of ethanol sold through E15 and E85 sales.[10] However, EPA finds it would be "inappropriate" to project increased E85 volumes based on either the "consumption capacity of all FFVs" (constraint 3) or by assuming that the "E85 throughput at a given station could be the same as typical throughput rates for E10" (constraint 2).[11]

Instead, EPA notes the volume of ethanol is primarily constrained by two factors associated with the fourth item concerning the pricing of E15 and E85 relative to E10: the limited pass-through of RIN value to retail prices[12] and the limited increase in consumer demand for E85 at greater discounts to E10.[13] It should be noted here that economists typically do not describe limited responsiveness to prices as a constraint, but rather market behavior that could be explained by other factors and potentially overcome by policy mechanisms.

The proposed rule cites analyses conducted by EPA that analyze historical E85 prices and E85 sales:

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8 *Ibid.*

9 81 FR 34,791.

10 *Ibid.*

11 81 FR 34,790.

12 "Similarly, RIN prices can continue to provide additional subsidies that help to reduce the price of E85 relative to E10 at retail, but the propensity for retail station owners and wholesalers to retain a substantial portion of the RIN value substantially reduces the effectiveness of this aspect of the RIN mechanism." *Ibid.*

13 "We have also found that greater E85 price discounts relative to gasoline have not been associated with the substantial increases in E85 sales volumes that some stakeholders believe have occurred, or could occur in the near future." *Ibid.*

- A memo authored by David Korotney examines historic market data to attempt to describe the relationship between E85 prices and volumes sold.[14] In looking at several sets of data he concludes that the relationship between volume of E85 sold per retail station and percent E85 discounts relative to E10 price is linear, and he uses data from five states to parameterize this linear relationship ("Five State data");
- A subsequent memo by Mr. Korotney that adopts the linear relationships between station sales and E85 price discounts, multiplies the average station sales by several estimates of E85 stations nationwide in 2017, and reports the projected total U.S. E85 volumes sold under various E85 price discount levels[15]; and
- A November 2015 memo by Dallas Burkholder explores price relationships in the supply chain from refiner, blender and retailer, and concludes that RIN price changes can affect blender and retailer margins – *i.e.,* that higher RIN prices do not always pass through to FFV customers in a one-to-one fashion, but rather are retained as additional profit by the blender or retailer.[16] This implies a lack of competition in the E85 market, which would attenuate the effect of RIN prices on E85 prices downstream, thereby reducing the impact of RIN price changes on E85 sales.

Although EPA's analysis confirms that (1) RIN prices influence the relative price of E85 and E10 at the pump and (2) motorists with FFVs respond to larger E85 discounts by purchasing more E85, EPA nevertheless concludes that these effects are extremely limited in the current market. Rather than providing confidence that the RIN mechanism works (albeit imperfectly) to expand E85 volumes well beyond the E10 blendwall levels, EPA instead constrains its 2017 E85 volume estimate to a slight increase over recent volumes. This E85 volume corresponds to a level roughly consistent with an EPA estimate of E85 sales volume expected when E85 is priced at energy parity with E10, *i.e.,* the retail price of E85 is below the price of E10 by an amount that reflects the lower energy content of E85.[17] EPA does not project the RIN price that would produce this result. Neither the E85 price discount nor the RIN price that would be necessary to achieve a particular E85 price discount are exogenous constraints but instead are endogenous results of policy choices, namely the RVO level EPA sets and the volume of E85 sales necessary to meet that RVO level. Put simply, the operative constraint here is the EPA's decision of where

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[14] Korotney, David, Memorandum to EPA Air Docket EPA-HQ-OAR-2015-0111, "Correlating E85 consumption volumes with E85 price," U.S. EPA Office of Transportation and Air Quality, 2015. (Korotney 2015)

[15] Korotney, David, Memorandum to EPA Air Docket EPA-HQ-OAR-2016-0004, "Estimating achievable volumes of E85," U.S. EPA Office of Transportation and Air Quality, 2016. (Korotney 2016)

[16] Burkholder, Dallas, "An Assessment of the Impact of RIN Prices on the Retail Price of E85," U.S. EPA Office of Transportation and Air Quality, November 2015. (Burkholder 2015)

[17] Korotney 2016, pp. 8 – 11.

to set the total volume requirement, not anything inherent in the market. This confusion between ends and means lies at the heart of the analysis that underlies the proposed rule.

B. Purpose of this Paper

In response to the proposed 2017 RVOs, we reviewed the EPA's approach to setting the volume requirements and analyzed the EPA's data to determine whether such a constraint exists in the pricing mechanism that will limit the ability of the existing regulations to incentivize further E85 sales if the EPA increases the RVOs further past the E10 blendwall.

From the perspective of economists and policy analysts experienced in describing the workings and limitations of markets, we outline in this paper why the EPA approach to using the historical data provides a limited view of the future. In particular, the extrapolation of data beyond its range runs counter to fundamental economic theory concerning consumer behavior when choosing between products that are close substitutes, and the analysis of RIN effects on E85 discounts sheds little insight into how supplier pricing might change when policy mandates substantial volumes of E85 for RVO compliance. We provide an alternative view of the likely response of the fuels market and consumer demand for E85 (a peek over the blendwall, if you will) if the EPA sets the total renewable fuel requirement based on additional volumes of ethanol sales in the form of E85.

We integrate the EPA analysis into an updated model of RIN price and E85 sales volume as described in Verleger (2014) in order to estimate the RIN price implied by the EPA analysis, and then revisit EPA's analysis of the key relationships.[18] Using revised estimates of market relationships we then project alternative future RIN price paths that correspond to expanded E85 sales volumes. This alternative model allows for the existing RIN pricing mechanism to alter the pricing behavior along the fuel supply chain and consumption choices of FFV owners, and produces far more reasonable results than the EPA analysis. Instead of imposing constraints or limiting E85 sales to those consistent with historic market prices, our model projects the RIN prices that would stimulate E85 sales necessary to meet various RVO levels.

II. The RIN Pricing Mechanism

The RFS is a market-based program for increasing the use of renewable fuels in the transportation sector. The program requires oil refiners to obtain sufficient credits, known as RINs, to cover their obligations as determined by their fuel sales and the annual RVOs. Every gallon of conventional gasoline and diesel fuel sold increases the obligation of refiners to obtain a bundle of RINs that represent volumes of conventional renewable fuel, advanced renewable fuel,

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18 Verleger, Philip K., The Renewable Fuel Standard: How Markets Can Knock Down Walls, January 2014. (Verleger, 2014)

and cellulosic renewable fuel. The RINs are separated and thus available for compliance when renewable fuels are blended into fossil fuels to create fuel products, such as E10, E15, and E85.[19] The fuels are then distributed to retail stations where consumers are able to purchase the fuel of their choice based on fuel availability, the relative prices of available fuels, and consumer preferences.

With increasing RVOs set by the EPA, refiners must obtain more RINs to cover their obligations. 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). For additional RINs to be generated though, higher volumes of transportation fuels that include renewable fuels or fuels with higher proportions of renewable fuel will need to be purchased at the retail stations (the other end of the supply chain).

At the heart of the issue and the proposed rule is the ability of E85 to overcome the "blendwall." We recognize that if E10 were the only fuel available for conventional gasoline-fueled vehicles that could constrain the consumption of ethanol as a component of transportation fuel by conventional vehicles. Without any other pathways for expanded ethanol consumption, 10% would indeed be a "blendwall"—RIN prices would soar without any additional ethanol being consumed.

But there are other options for increased ethanol use, which higher RIN prices can stimulate. Expanded use of E15, which most vehicles on the road today can use, is one. Another is provided by the roughly 3,100 stations – and growing, as EPA estimates about 3,700 stations as a mid-point projection in 2017 – that offer E85, and the fleet of about 20 million flex-fuel vehicles (FFVs) that can use E85.[20] In fact, the blendwall is really a blend *step*, with the height of the step being a function of the relative prices between higher-blend fuels (e.g., E85 and E15) and E10 that stimulate additional sales of the higher-blend fuels. Overcoming this blend step requires additional ethanol usage and RIN generation through increased sales of higher-blend fuels. This paper only analyzes the ability of E85 to get over the blend step, but that focus does not mean that E15 could not assume an important role in accomplishing that goal.

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19 E15 is gasoline blended with up to 15 percent ethanol that represents another pathway to overcome the E10 blendwall. Expanding E15 sales into conventional vehicles raises different issues than those that surround the expansion of E85 sales into FFVs; those issues are beyond the scope of this paper. Accordingly, we do not analyze how E15 sales may contribute to meeting RVOs.

20 The Energy Information Administration *2016 Annual Energy Outlook Early Release* Table 40 estimates 19.6 million FFVs are on the road in 2016 (3.7 million cars and 15.9 million light trucks) and 20.94 million in 2017. EIA, 2016. EPA states that there were 3,126 E85 stations as of March 2016 and estimates about 3,700 for 2017. Korotney 2016, pp. 6, 8. E85prices.com currently tracks 3,454 stations selling E85.

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 emphasized in the EPA proposed rule will only lead to so much growth in E85 market share on its own. Reaching the levels necessary to meet the goals of the RFS will require a price signal from the RIN market to incentivize lower E85 prices at the pump.

The RIN mechanism provides the means for reducing the price of higher-blend fuels to consumers. When refiners demand more RINs as a result of higher RVO levels, and are willing to pay a higher price for them, the value transferred to blenders of E85 will result in lower prices at the pump for higher-renewable fuel products. Blenders have the option of holding onto the revenue they obtain through RIN sales or decreasing the E85 price, effectively passing the RIN revenues to consumers. The price at which consumers will start purchasing more and more E85 then becomes the crucial aspect for determining what a reasonably achievable level of E85 sales will be in the near future.

The analysis described below considers the relationship between RVO levels, RIN prices, retail prices of E10 and E85, and E85 sales. It is necessary to model the structure of the RIN market and transportation fuel supply chains to understand how additional RINs are generated and how RIN price effects would flow through to the pump. 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 costs and benefits of RFS compliance, changes in profit margins, and how consumers' purchasing decisions change when E85 prices vary. In the next two sections we provide an analysis of the elements of the supply chain that the EPA considered in their approach to setting the 2017 RVOs and alternative perspectives on the role of RINs in incentivizing increasing E85 sales.

III. Consumer Choice for FFV Drivers

A. The Economics of Close Substitutes

FFV owners that drive into a retail station with both an E10 pump and an E85 pump have a choice between fuels for filling up their tank.[21] The two fuels are potential substitutes since both products provide the energy necessary for driving the car. However, the fuels are not perfect substitutes since the E85 fuel contains less energy per gallon and FFV drivers will need to re-fill more frequently when running on E85. More frequent trips to retail stations impose an additional cost on E85 users. The differences in energy content, and the resulting additional

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[21] E15 could also be a choice for FFV drivers, but we are not addressing that fuel in this report.

transaction costs, mean that most consumers will purchase E85 only if its price per gallon is substantially lower than E10.

E10 and E85 are what economists call "close substitutes" for FFV owners; an increase in the price of one leads to an increase in the quantity demanded (by FFV owners) of the other, as most FFV owners would be willing to shift their purchases from one to the other when prices change. The necessary discount for E85 (whether in absolute terms or as a percentage of E10 price) for an FFV owner to be indifferent between filling his/her tank up with E10 or E85 will depend on several factors, including the energy content of the fuels, the capacity of the vehicle's gas tank, and the opportunity cost of the owner's time. However, it is clear for a given price of E10 that the percentage of FFV owners switching to E85 will increase with the size of the discount. Furthermore, the economics of close substitutes imply that there exists a relatively narrow range of relative prices in which a majority of consumers switch from one product to the other.

Generally, the assumption has been that consumers will reach this inflection point and purchase more E85 when E85 is priced at a discount sufficient to account for the decreased energy density of the fuel. Based on the average ethanol content of E85, the discount for achieving energy price parity is about 22%.[22] However, a consumer who purchases E85 solely due to its economic savings may require a somewhat larger discount to account for the costs of seeking out less common E85 pumps and filling up more often.

The additional transaction costs of purchasing E85 will generally be fixed and not a function of gasoline prices, so that the discount necessary to achieve different levels of E85 sales will differ depending on the price of regular gasoline. For example, an FFV owner who incurs a constant transaction cost each time they refuel their vehicle will require a slightly higher price discount (in percentage terms) when E10 prices are low than when they are high. Finally, some evidence suggests that consumers are more cognizant of absolute price differentials than price ratios. Analysis by the Fuels Institute found that E85 price reductions of around $0.50 tend to result in the most E85 sales and that the price reduction is more consequential than the percentage discount.[23] A consumer who would require a $0.50/gallon price discount on E85 to select E85 would purchase E85 at a 14% discount when the E10 price is $3.50/gallon but a 25% price discount when E10 is selling for $2.00/gallon. These nuances in consumer behavior suggest that consumers are somewhat different in their perceptions of E85 prices, but much more likely to purchase E85 when the E85 discounts are largest in absolute or relative terms, and very unlikely to purchase E85 when perceived discounts are not sufficient. These observations also are

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22 We make similar assumptions to the EPA that the average ethanol content in E85 is 74%. 81 FR 34,786.

23 "Consumers are focused on the absolute price differential, not the percent change, and that price discount need not be equal to the energy differential." Fuels Institute, *E85 – A Market Performance Analysis and Forecast*, 2014, p. 36.

consistent with a demand curve that reflects a price threshold that motivates a substantial number of potential FFV owners to fill up with E85, *i.e.,* a non-linear relationship between E85 price (or price discount relative to E10) and volumes sold. A complete analysis of consumer behavior regarding E85 and E10 choices is beyond the scope of this analysis; we adopt a relative price variable equivalent to the EPA parameter to explain consumer choices in our analysis.

B. Review of Korotney Analysis

The 2015 Korotney memo mentions that non-linear functional forms have been suggested as describing the relationship between E85 price discounts and the volume sold, but his analysis concludes that "only a minority of the available data demonstrate a nonlinear relationship."[24] Instead, the analysis in the Korotney memo implies that E85 sales will rise by a constant factor as the E85 price discount increases, regardless of how close the price discount is to energy parity. In our review of the Korotney analysis, we found several shortcomings in his analysis that lead us to conclude that the available public data instead suggest a non-linear relationship between the E85/E10 price discount and E85 demand, consistent with what one would expect as the relative prices of close substitutes change. Our appraisal of Mr. Korotney's statistical analysis is found in Appendix A.

In brief, we find that Mr. Korotney performs only a cursory analysis of public data to determine the responsiveness of E85 sales volumes to price discounts, and does not even analyze the Five-State data to determine if those relationships were linear or non-linear. Although it is true that the Five State data has limited observations in the energy parity range (only 15% of observed monthly price discounts are 22% or higher), when we estimate regressions with seasonal and annual "dummy" variables we gain substantial explanatory power, improve the precision of the coefficients that measure price response and can compare how well various functional forms fit the data. We find a slight but consistent advantage to non-linear functional forms in terms of fitting the Five State data. This suggests that larger E85 price discounts will deliver greater than proportional increases in volumes sold to FFV consumers when the discounts approach energy parity or exceed that level. We also illustrate the perils of relying on the coefficient derived from simple one-factor linear regressions, when significant variables are omitted. Appendix A describes the case of California, showing that the slope that Mr. Korotney derives from his analysis bears no relationship to the actual relationship between E85 price discount and volumes sold. Our analyses thus calls into question the reliability, accuracy and interpretation of all of Mr. Korotney's individual slope coefficients in his exploration of the Five State data, and by extension his composite demand relationship.

Beyond the challenge of trying to determine the functional form without sufficient data to do so, extending the analysis to the energy parity point and beyond with extremely limited data in that range is unlikely to capture the relationship expected for close substitutes around an indifference

24 Korotney, 2015, p. 16.

price. The limit of this approach can be seen by examining the implications of extrapolating the linear functional form well beyond the energy parity point. Assuming, for example, that the price discount reaches a full 100% discount, such that E85 is given away for free, the total E85 sales would be about 660 million gallons per year under the assumed linear relationship, only 2.9 times the roughly 230 million gallons per year Mr. Korotney finds for the energy parity point.[25] Given the fueling infrastructure and on-road FFV fleet, we believe that free E85 would command more than about 4 percent of the potential annual market for FFV fuel.[26]

In fact, limited consumer response to E85 prices that are not near the energy parity point is to be expected. The relatively inelastic, non-price sensitive nature of the linear fit that Mr. Korotney identifies is due in part to the fact that much of the current E85 volume sold is to consumers willing to pay higher prices for a renewable fuel (perhaps due to environmental preferences) or to government employees who are required to purchase E85 due to federal or state fleet mandates.[27] When relatively limited sales of E85 are necessary to meet the refiner's RIN obligations, the early adopters and those required to purchase E85 (both of which tend to be less price sensitive) will satisfy the RIN requirements at E85 prices that need not fall to the energy parity point. Price insensitive consumers will purchase E85 regardless of the prices, resulting in the limited increases in demand at lower prices. The assumption in the Korotney analysis is that a similar trend will continue as E85 prices fall further to the energy parity price and below. This assumption does not account for the likely consumer response by the FFV drivers that are driven primarily by relative price considerations.

C. Historical Analysis of E85 Volumes and Prices

All evidence we reviewed (including the Korotney memos) clearly reflects a downward sloping demand curve for E85; sales of E85 to current FFV owners increase as the price of E85 decreases (relative to E10).[28] The primary point of contention is the relationship between price and volume, and how that volume relationship might change as E85 and E10 prices approach and surpass energy parity. Once the discount is sufficient to make it worthwhile for FFV drivers, we

25 See Korotney 2016, assuming Five State data and 3,700 stations selling E85 during 2017.

26 This calculation assumes that the 2017 FFV fleet, if fueled exclusively with E85 (about 820 gallons per year average consumption) would consume approximately 17.13 billion gallons per year. Air Improvement Resource, Inc.. *Analysis of Ethanol-Compatible Fleet for Calendar Year 2017*, pp.1-2.

27 For a more detailed discussion of E85 customer segmentation, see Stillwater Associates LLC, Infrastructure Changes and Cost to Increase Consumption of E85 and E15 in 2017, July 11, 2016.

28 Our use of the term "downward sloping" here refers to conventional economic graphical analysis, in which price is on the Y-axis and quantity is on the X-axis. Strictly speaking, the Korotney graphs are upward-sloping, but that is due to his construction of graphs and the variables he has chosen (*i.e.* discount rather than price level). Despite this presentational difference, his graphs are consistent with conventional economic wisdom that consumers will generally purchase more of a good or service as the price decreases, all things equal.

expect the nature of E85 and E10 as close substitutes will result in significant quantities of E85 sales. Due to the nature of close substitutes, the relationship between E85 prices and volumes should reflect a significant increase in sales when the price discount is sufficient to account for the difference in energy content and transaction costs, as described above. This implies a functional form that has some curvature in this range, *i.e.,* sales volumes that are more sensitive to price discounts in the range where most consumers might be indifferent between the two fuels.

This is supported by periods of much higher volumes observed in the past when E85 is priced favorably. For example, analysis in Verleger (2014) found that Minnesota consumers increased E85 purchases significantly when the discount approached the energy-price parity point.[29] A similar shape was identified in the Babcock and Pouliot paper that analyzed E85 sales in regional markets.[30] Analysis by Oak Ridge National Laboratory for incorporating E85 demand into the National Energy Modeling System ("NEMS") model resulted in the following conclusion:

> *Choice of E85 appears to be highly price elastic. The elasticities inferred in this study are somewhat higher than those of previous econometric analyses. However, this is consistent with the greater preponderance of non-fleet (public) E85 sales in the more recent Minnesota data. It is also consistent with the observation that, for FFV owners, E85 and E10 are close substitutes. Controlling for prices and availability (as the model attempts to do), the only practical difference is the lower energy content of E85.*[31]

We also find the Minnesota Department of Commerce data useful to examine the relationship between E85 price, E10 price, and E85 sales volume per retail station, as we explain in Appendix A. We explored several functional forms and took seasonal factors into account to explain variation in monthly E85 sales volume (gallons) per retail station selling E85. The best fits were log-level and log-log specifications that included annual and monthly dummy variables to account for fixed effects.[32] A comparison of the functional forms shows that once seasonality is

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29 Verleger, 2014.

30 Babcock, Bruce and Sebastien Pouliot, How Much Ethanol Can Be Consumed in E85?, Briefing Paper 15-BP-54, September 2015.

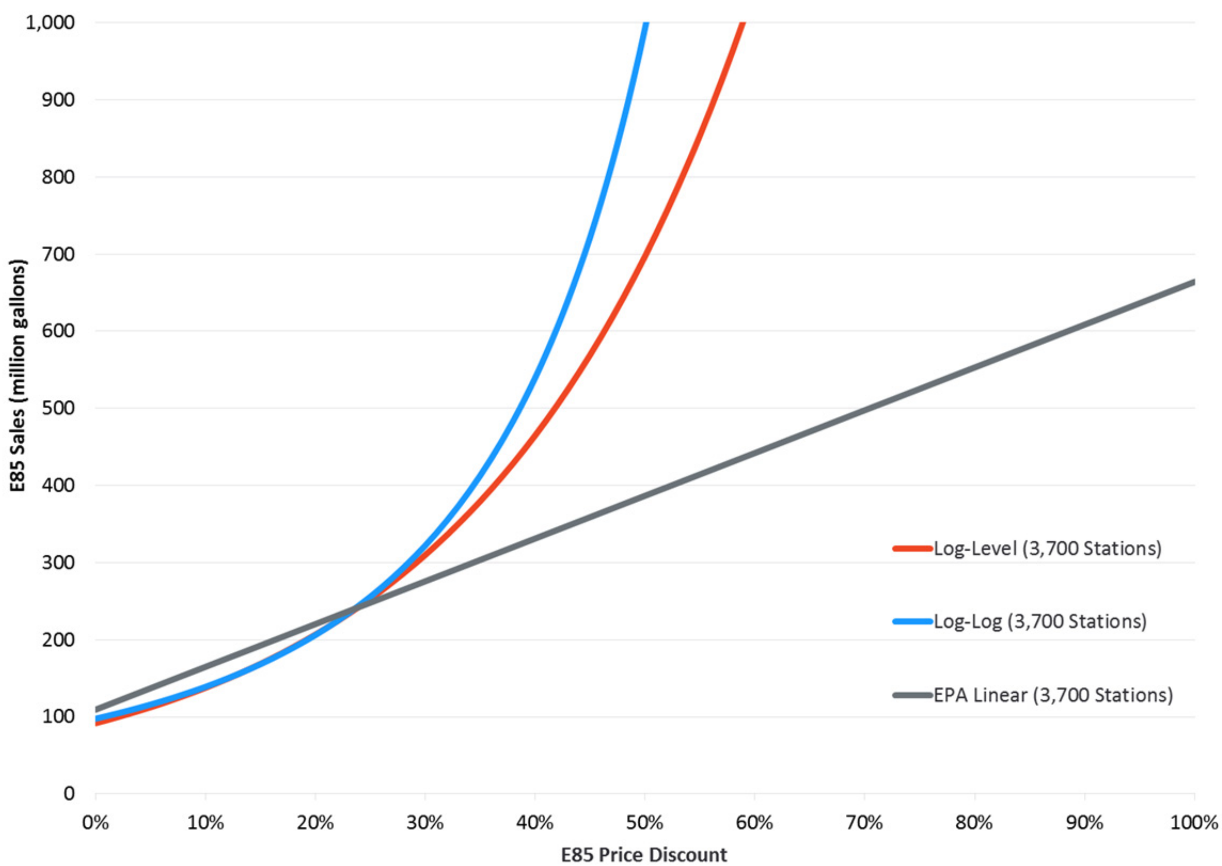
31 Liu, Changzheng and David L. Greene, Modeling the Demand for E85 in the United States, ORNL/TM-2013/369, September 2013, p. 31. Available at: http://info.ornl.gov/sites/publications/files/Pub45616.pdf.

32 For clarity, we use "log-log" and "log-level" to refer to our models, as the term "log-linear" has been applied more generally to any regression where the dependent variable is log-transformed. In our "log-log" specification, both the dependent variable (E85 sales per station) and the independent variable of interest (the ratio of E85 to E10 prices) are transformed with the natural log function prior to estimation. In our "log-level" specification, only the dependent variable is log-transformed. Details are available in Appendix A.

taken into account, both the log-log and log-level functional forms fit the observed data better than the linear functional form.

When we scale the Minnesota results for EPA's middle estimate of 3,700 total E85 stations in 2017, we derive demand relationships as shown on Figure 1. Figure 1 shows the two demand relationships from the Minnesota data regressions, along with the demand relationship found in Korotney.[33]

Figure 1: Nationwide E85 Sales as a Function of E85 Price Discount in 2017 (3,700 Stations)



The relationships between the two logarithmic specifications and the linear relationship are instructive. First, all of the demand relationships give about the same E85 volume at price parity (E85 price discount of 22%) of 220 – 230 million gallons per year. After that point, however, the linear relationship diverges radically from the non-linear relationships. At a 50% discount, the Korotney linear relationship suggests E85 sales of 387 million gallons, while the two logarithmic

33 Korotney, 2016.

functions give E85 sales of 697 million gallons per year (log-level) and 993 million gallons per year (log-log). To sell 660 million gallons per year, the Korotney linear demand relationship implies a 100% discount, *i.e.,* that E85 is available at a price of zero, while the non-linear demand relationships suggest discounts below 50% would suffice. One limitation common to all logarithmic specifications is the lack of offsetting constraints at very high volumes that would give the vertical sections a rightward bend toward some volume limit. Thus, we truncate the graph at 1.0 billion gallons per year, or roughly 23,000 gallons per month from 3,700 stations. According to the Stillwater analysis, this is well within the fueling throughput of a typical E85 station of 45,000 gallons per month.[34]

One source of potential conservatism in our analysis is that, like Korotney, it is based on data in which E85 prices remained below parity for only short periods of time. Thus, the regression would not fully capture the consumer response that might result if the market were to stay at those same levels below parity for more sustained periods, allowing for expanded customer awareness and more aggressive retail marketing.

Figure 2 shows the same results for 4,500 stations. Increasing the assumed number of stations in 2017 to 4,500 stations shifts the corresponding sales volumes up for any level of E85 price discount.

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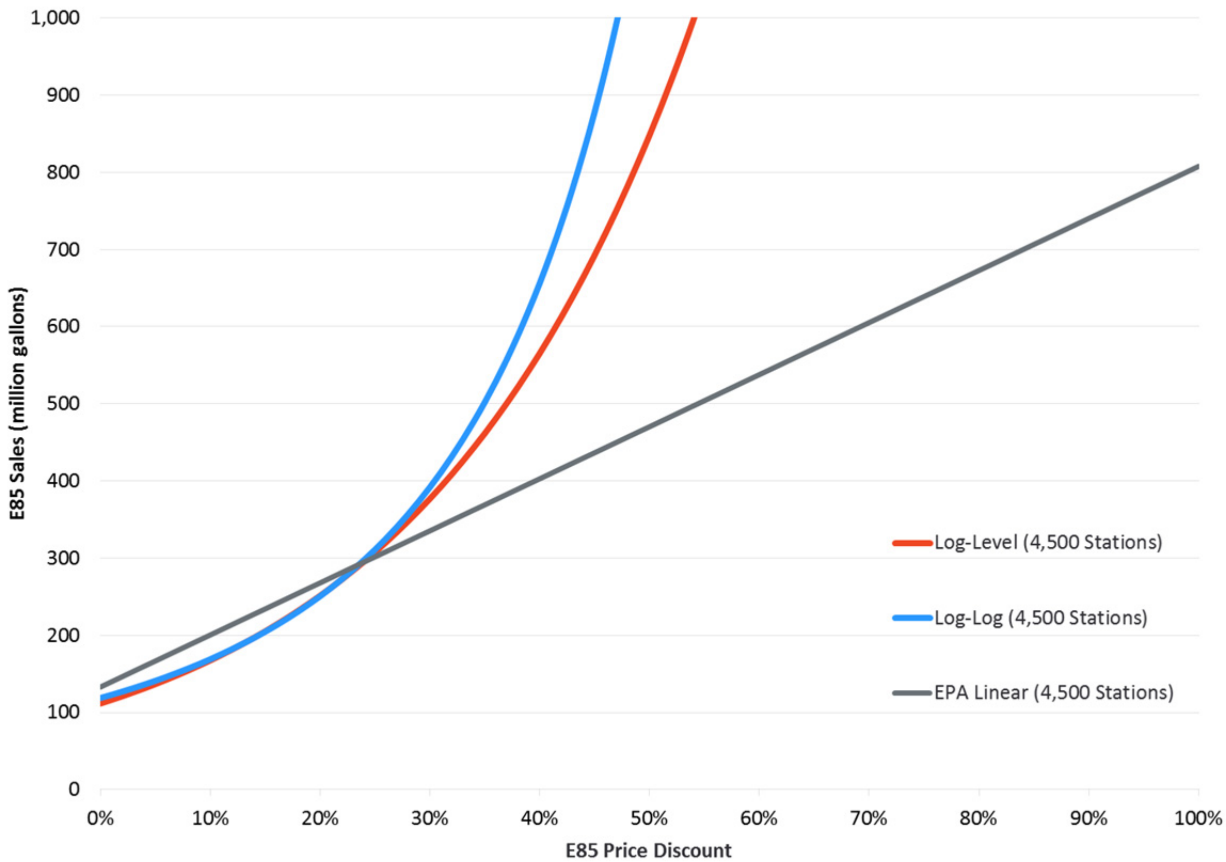
34 Stillwater Associates LLC, Infrastructure Changes and Cost to Increase Consumption of E85 and E15 in 2017, July 11, 2016. It should be noted that extrapolation of non-linear demand relationships well beyond the range of observed data may not account for other constraints or frictions on either the supply or demand side.

Figure 2: Nationwide E85 Sales as a Function of E85 Price Discount in 2017 (4,500 Stations)



Below we present these numbers in table form, excluding values that surpass a dispenser throughput of 45,000 gallons per month.

Table 1: Nationwide E85 Sales as Function of E85 Price Discount in 2017

E85 Price Discount	Million Gallons/year (at 3,700 stations) EPA Linear	Log-Level	Log-Log	Million Gallons/year (at 4,500 stations) EPA Linear	Log-Level	Log-Log
0%	109	92	98	133	112	119
5%	137	112	116	167	137	141
10%	165	138	139	200	168	169
15%	193	169	168	234	205	205
20%	220	207	206	268	251	251
22%	231	224	224	281	273	273
25%	248	253	256	302	308	311
30%	276	310	322	335	377	392
35%	304	380	413	369	462	502
40%	331	465	540	403	565	656
45%	359	569	722	437	693	878
50%	387	697	993	470	848	1,208
55%	414	854	1,413	504	1,039	1,719
60%	442	1,046	n/a	538	1,272	n/a
65%	470	1,281	n/a	572	1,558	n/a
70%	498	1,569	n/a	605	1,909	n/a
75%	525	n/a	n/a	639	n/a	n/a
80%	553	n/a	n/a	673	n/a	n/a
85%	581	n/a	n/a	707	n/a	n/a
90%	609	n/a	n/a	740	n/a	n/a
95%	636	n/a	n/a	774	n/a	n/a
100%	664	n/a	n/a	808	n/a	n/a

Note: "n/a" indicates that implied sales are above 45,000 gallons per month per station.

IV. Blender-Retailer Transactions and Margins

A. Maximizing Blender Profits

The blenders and distributors play a central role in the RIN and E85 market. As the connection between the wholesale and retail suppliers, the blenders separate the RINs from the neat ethanol purchased from ethanol producers. Competitive conditions at the blender level and consumer preferences together determine the extent to which blenders can retain the value of RIN sales made to refiners as higher margins (rather than passing the RIN value downstream to retail station buyers). The portion of the value of RINs that is not retained can be passed through to retailers (and eventually consumers) through their pricing of wholesale E10 and E85.

As noted in the Burkholder memo, the goal of the blenders is to maximize their profits, which does not necessarily align with the goal of selling increasing quantities of E85 under current market conditions. Based on the relatively inelastic demand for E85 at current market conditions, and some assumed market power at the blending and/or retail station level, increasing E85 sales by way of greater price discounts will reduce profits since the price drop will be larger than the gain in volume. However, if the same profit maximizing calculation was performed at a portion of the demand curve where small changes in price resulted in significant increases in sales, the profit maximizing goals of the distributor will begin to align with the goals of the RFS program.

For this reason, we expect the blenders in the current market not to pass through all of the RIN value, but instead to retain some in the form of higher margins because the discounts will not drive additional sales. We expect this relationship to change if significantly greater volumes of E85 sales are necessary to meet the future RVOs. That is because recent RVO levels and the proposed RVO, set close to the E10 blendwall, could be satisfied by consumption in a relatively elastic portion of the demand relationship, as reflected in the non-linear functional forms depicted earlier. In order to meet a higher RVO, therefore, RIN prices rise to the level where blenders face stronger incentives to reduce E85 price (i.e, reduce their margins) in order to drive needed volumes. Once the market volume reaches the inflection point or a more price-elastic segment of the demand curve, then a virtuous cycle of higher volumes and lower blender margins (while still profitable) can create the required E85 volumes and provide obligated refiners sufficient RINs to meet much higher RVOs.

However, the lack of a full pass-through does not "reduce the effectiveness of this aspect of the RIN mechanism" as the EPA claims.[35] The RIN price is a function of the amount of RINs required to meet the RVO (demand) and the amount of RINs separated by blenders (supply). If RIN value is held up by the blenders, the RIN price will increase since a fixed amount of renewable fuels (likely E85 or potentially an alternative renewable fuel) will need to be sold for refiners to comply with the RVO requirements. An increase in RIN value, even with a constant percentage pass-through, will lead to lower E85 price and additional incentive for FFV consumers to purchase E85 instead of E10.

B. HISTORICAL ANALYSIS OF RIN AND E85 PRICES

Using national average retail E85 and wholesale ethanol prices, Burkholder estimates the relationship between the retail E85 price and RIN prices, finding that a $1 increase in the RIN price increases the retail markup on E85 by $0.40. Since it takes roughly 1.4 gallons of E85 to

[35] 81 FR 34,790.

generate a D6 RIN, this implies that only $0.44 of each dollar in RIN value is passed through to consumers in the form of lower prices for E85.[36]

The use of national data to capture pass-through dynamics in what are inherently regional markets may mask important variation in pass-through rates. Similarly, additional time has passed since the Burkholder analysis was completed, meaning additional data has accumulated. Finally, consideration of seasonal factors and other changes over time can also lead to better estimates of pass-through. We have revisited Burkholder's analysis of E85 pass-through, using data that both cover a longer period of time and depict state-specific prices and accounting for seasonal and annual factors, and we have generated results that, while roughly consistent with his conclusion that RIN value is only partially passed through to retailers, point to higher and more varied rates of pass-through.[37] Additional details of our analysis are found in Appendix B.

Specifically, we first replicated Mr. Burkholder's results for the January 2013 through July 2015 period, using data that appears to be very similar to that used by Mr. Burkholder. Our results are similar (although we note that his interpretation of those results may yield a slight understatement of the implied pass-through). We then estimated that same equation using a longer time period (August 2012 through March 2016), reflecting all currently available data. These results indicate that the pass-through is 55%, somewhat higher than Mr. Burkholder's finding of 44% pass through at the national level. Next, we estimate a state-specific variant of these full-sample results for two states with relatively well-developed E85 markets, while maintaining the same basic methodological approach.[38] We do this both before and after accounting for seasonal and annual factors. While our results are consistent with Burkholder in finding that pass-through is incomplete, historical experience in well-developed markets is suggestive of higher pass-through rates. Most notably, in Minnesota, a state that is known to have relatively mature E85 wholesale distribution and retail markets, the implied pass-through is even higher, at about 65%. These results are obtained using a time period during which the

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36 1-0.4*1.4 = 0.44. Incidentally, Burkholder calculates the cost of production of a gallon of E85 by assuming that neat ethanol is mixed with E10 gasoline. However, in calculating the 1.41 adjustment factor he uses to translate his regression result to a pass-through rate, he fails to account for the fact that E10 also results in the production of RINs. A corrected adjustment factor of 1.35 implies a slightly higher pass-through rate of 46%.

37 Verleger 2014 also noted that historical evidence was not consistent with perfect pass-through. See pp. 30-32.

38 Specifically, our construction of the monthly retail mark-up which is used as the dependent variable relies on monthly E85 retail price data from E85prices.com, a monthly average of daily state-specific wholesale ethanol prices from USDA, and a monthly average of the daily Chicago spot price for CBOB. Use of the Chicago CBOB price (*i.e.,* the price blenders paid for their blendstock) instead of a national wholesale regular gasoline price maintains consistency with the use of wholesale ethanol prices in that both reflect input prices for blenders. It also is more geographically relevant to those states that have significant E85 production and consumption.

market determined E85 sales, not an RVO set well beyond the blendwall that would mandate substantial volumes of E85. During most of this time period, the E85 and E10 prices were in a relatively inelastic segment of the demand relationship (the curve relating the E85 price discount to E85 sales volumes). Thus, we believe that the market reflected less competitive conditions and less aggressive discounting than would likely occur in the event of a market need for additional RINs to comply with a more ambitious RVO. In that regard, we view 55% to 65% margin pass-through as a lower bound, conservative estimate of likely supplier behavior under more ambitious RVOs. It would be entirely reasonable to expect much higher pass-through percentages on the part of blenders and retailers competing for a larger share of a rapidly growing E85 fuel market. In the analysis that follows, we utilize two assumed RIN pass-through percentages: 50% and 75%, corresponding roughly to the current market under relatively inelastic E85 demand and a market incentivized to expand E85 sales to meet more ambitious RVOs than proposed.

V. Beyond the Blendwall

A. RIN Prices and E85 Volumes

To relate RIN prices and 2017 RVO levels, we utilize an updated version of the model described in Verleger (2014).[39] We refresh the market data, for example, with 2017 prices of blendstock and ethanol based on current futures markets and fuel volumes consistent with the Short Term Energy Outlook (STEO).[40] The model accounts for national fuel volumes and prices using an accounting framework of the supply chain linked to an empirically-derived demand relationship that relates the E85/E10 price ratio (1-discount) to E85 sales.

As an initial matter, we calibrate the analysis framework to EPA parameters by adopting Mr. Korotney's linear demand relationship (scaled up to 3,700 stations, the middle figure of Mr. Korotney's range of station numbers) and assuming Mr. Burkholder's finding of 44% RIN value pass-through into E85 prices. The model then solves for RIN prices at various levels of E85 volumes. This resulting relationship between RIN prices and E85 sales volumes is shown on Figure 3, which shows the RIN prices that would enable various levels of E85 had EPA analyzed the integrated supply-demand relationships instead of examining various pieces in isolation.

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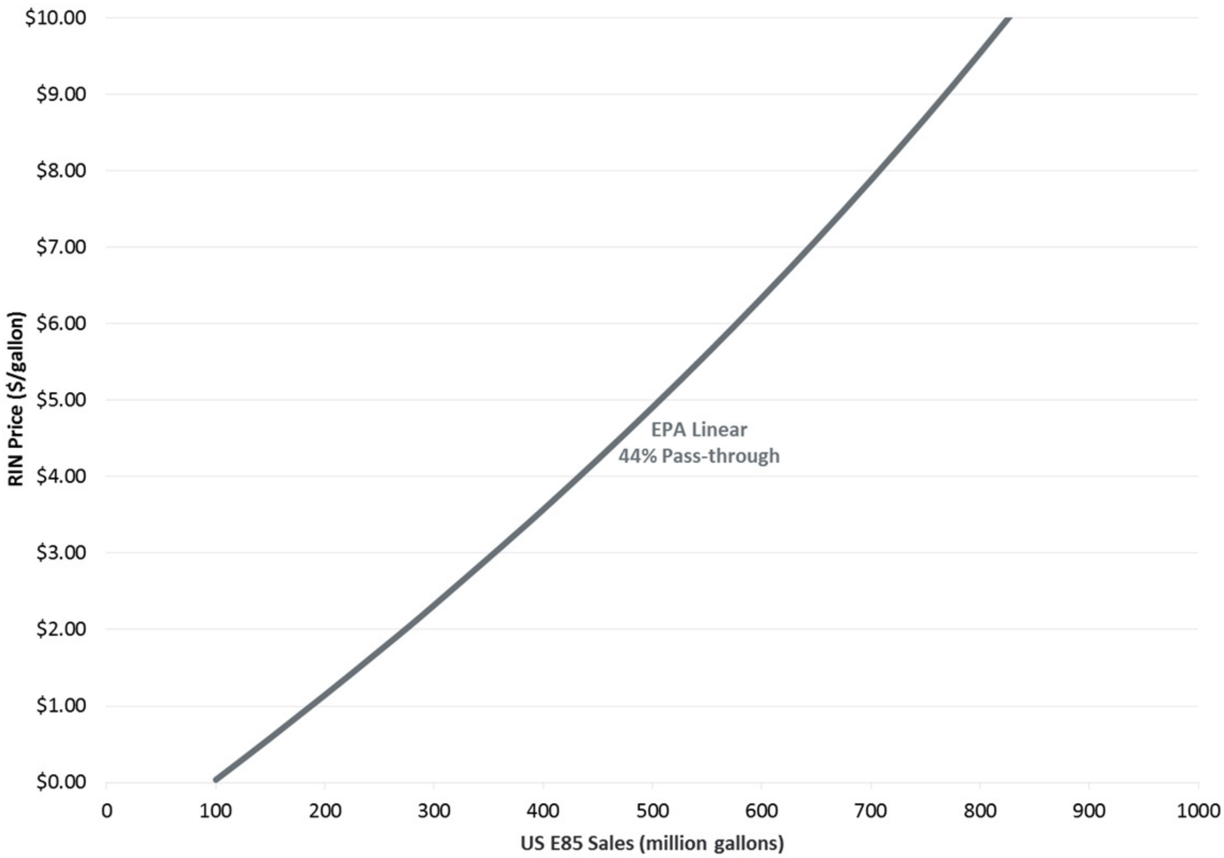
[39] See Verleger (2014) Appendix B "RIN Pricing Analysis Framework" for a description of the model and data requirements. We removed the $0.10 per gallon "E85 Equipment Adder" referenced in Table B-4 and Equation 4 for calculating the retail profit margin for E85 from our analysis.

[40] Ethanol and RBOB Gasoline futures prices are from the CME Group website (http://www.cmegroup.com/) and were downloaded on June 7, 2016. Gasoline and ethanol demand are consistent with the values in the EPA's proposed rule setting 2017 RVOs, which are based on the EIA's Short-Term Energy and Summer Fuels Outlook for April 2016.

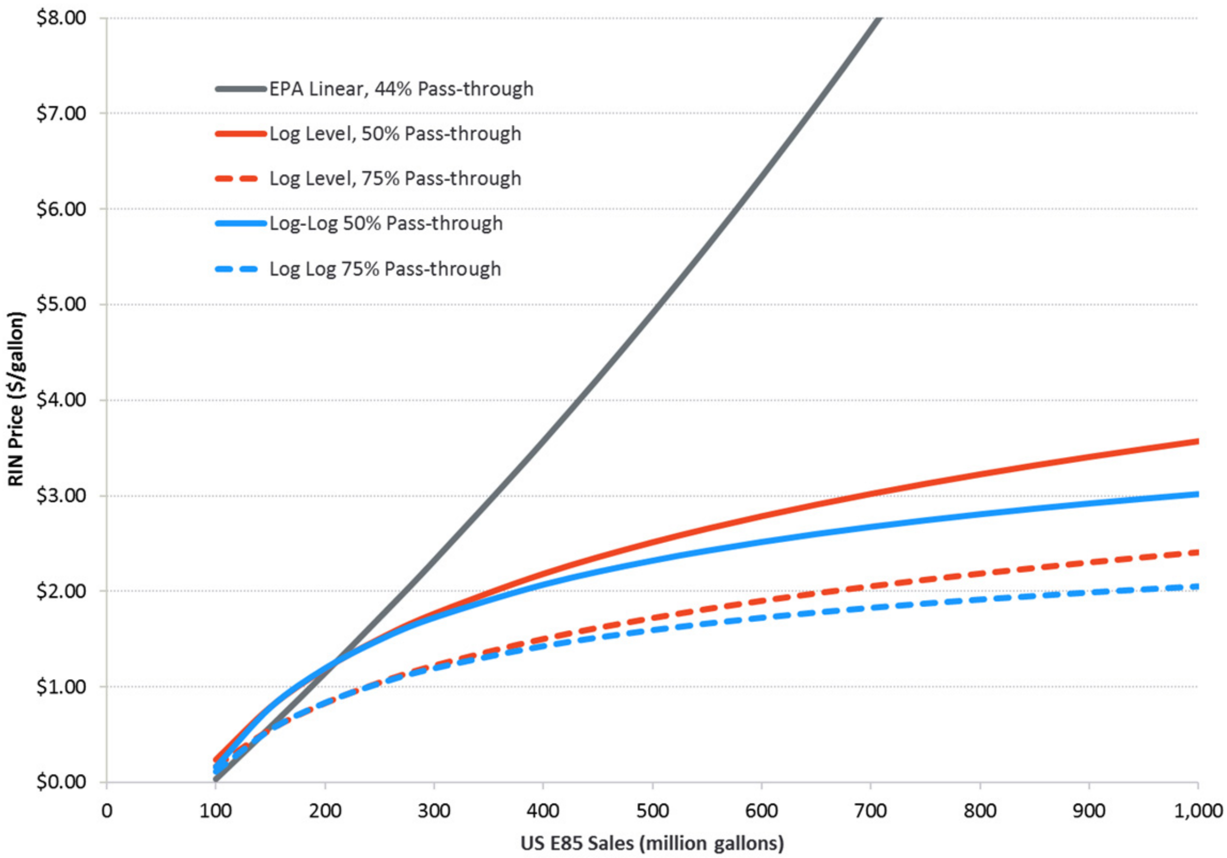
Figure 3: 2017 RIN Prices and E85 Sales Using EPA Findings (3,700 Stations)



As is evident from the figure, the combined effects of a linear demand relationship and a limited pass-through of RIN value to E85 prices implies extremely high RIN prices for modest increases in E85 volumes. For example, the 200 – 400 million gallon E85 volume range cited in the proposed rule would correspond to RIN prices in the range of $1.15 and $3.57, much higher than recent RIN prices (about $0.80) if the RIN price estimate is based on the demand relationship suggested in the Korotney analysis and the pass-through percentages suggested in the Burkholder analysis. The steep increase in RIN prices to achieve a very modest increase in E85 volumes suggests EPA has not assessed the validity of those internal analyses based on the plausibility of the composite model results.

In order to provide more plausible estimates, we adopt the non-linear demand relationships described above, examine cases with 3,700 and 4,500 stations, and assume 50% and 75% RIN value pass-through to account for evolving blender and/or retail margins. Figure 4 shows the relationship between E85 volumes and RIN prices using the log-level and log-log demand relationships, scaled to 3,700 retail stations, under 50% and 75% blender pass-through assumptions. These relationships imply RIN prices in a much more modest range for E85 volumes approaching 1.0 billion gallons per year.

Figure 4: 2017 RIN Prices and E85 Sales Using Brattle Findings (3,700 Stations)



As seen in Figure 4, even if blender RIN price pass-through remained at 50%, 200 million gallons of E85 sales could be supported under a RIN price at the same level (about $1.20) under either of the non-linear demand relationships, but 400 million gallons would raise RIN prices only to $2.18 (log-log) or to $2.07 (log-level), much lower than the corresponding EPA linear relationships RIN price ($3.57). If blender margins fell and RIN value pass-through reached 75%, as we would expect under more competitive markets, 400 million gallons of E85 would only require RIN prices of $1.43-$1.50. At the $3.57 RIN price level, we estimate that over 1 billion gallons of E85 would be sold under all of our projections for 3,700 stations in 2017.

Estimated RIN prices are lower, and/or E85 volumes higher, when 4,500 stations are assumed in 2017. This is shown in Figure 5, along with the corresponding EPA linear relationship. Table 2 below gives the results shown in the figures above in tabular form for reference.

Figure 5: 2017 RIN Prices and E85 Sales Using Brattle Findings (4,500 Stations)

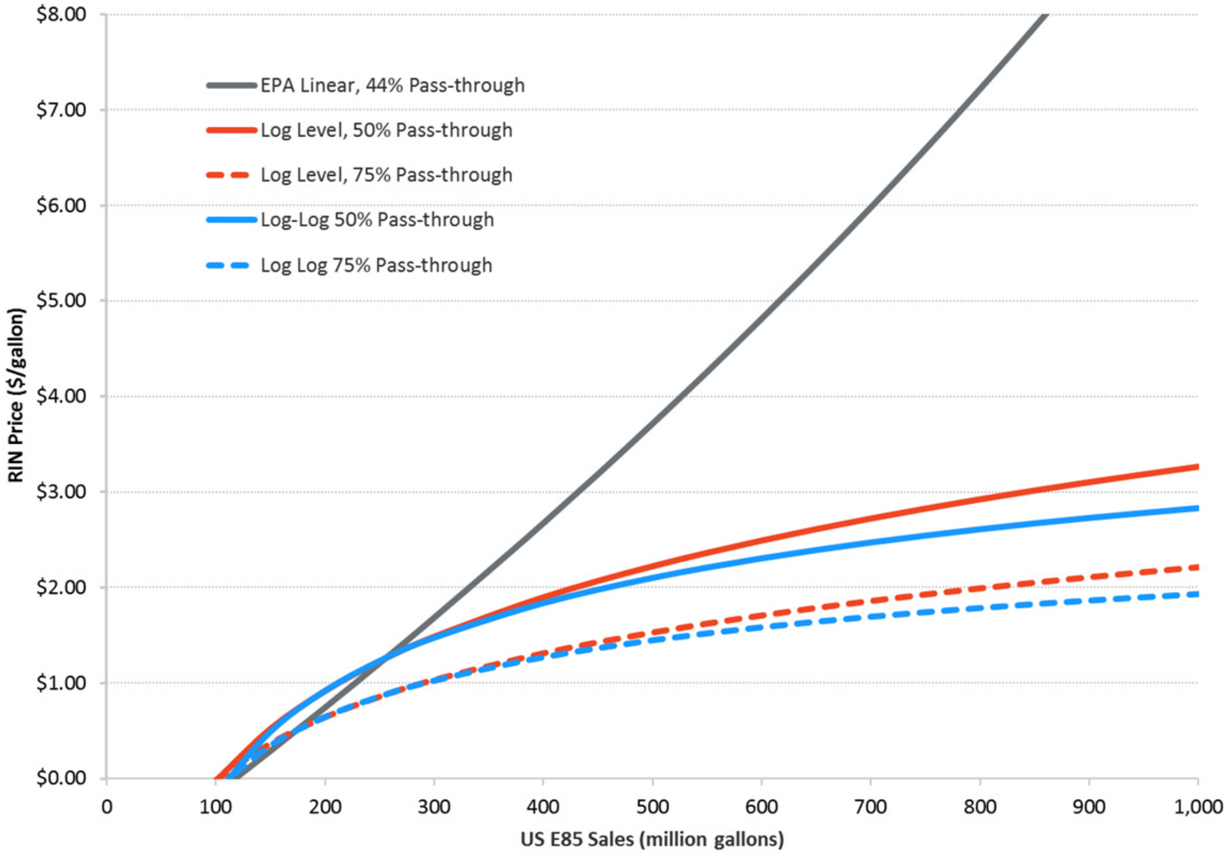


Table 2: 2017 RIN Prices and E85 Sales Using Brattle Findings

	3,700 Stations					4,500 Stations				
	EPA Linear	Log-Level		Log-Log		EPA Linear	Log-Level		Log-Log	
Volume (Million Gallons E85 per Year)	44% Pass-through	50% Pass-through	75% Pass-through	50% Pass-through	75% Pass-through	44% Pass-through	50% Pass-through	75% Pass-through	50% Pass-through	75% Pass-through
100	$ 0.04	$ 0.24	$ 0.17	$ 0.16	$ 0.12	$ (0.15)	$ (0.02)	$ (0.02)	$ (0.16)	$ (0.11)
150	$ 0.58	$ 0.79	$ 0.56	$ 0.79	$ 0.55	$ 0.29	$ 0.52	$ 0.37	$ 0.49	$ 0.35
200	$ 1.15	$ 1.19	$ 0.83	$ 1.20	$ 0.83	$ 0.74	$ 0.92	$ 0.64	$ 0.92	$ 0.64
250	$ 1.73	$ 1.51	$ 1.05	$ 1.49	$ 1.04	$ 1.21	$ 1.23	$ 0.86	$ 1.23	$ 0.86
300	$ 2.32	$ 1.77	$ 1.22	$ 1.73	$ 1.20	$ 1.69	$ 1.49	$ 1.03	$ 1.48	$ 1.03
400	$ 3.57	$ 2.18	$ 1.50	$ 2.07	$ 1.43	$ 2.67	$ 1.90	$ 1.31	$ 1.84	$ 1.27
500	$ 4.91	$ 2.51	$ 1.72	$ 2.32	$ 1.60	$ 3.72	$ 2.22	$ 1.53	$ 2.10	$ 1.45
600	$ 6.34	$ 2.79	$ 1.90	$ 2.52	$ 1.72	$ 4.82	$ 2.49	$ 1.71	$ 2.31	$ 1.58
700	$ 7.88	$ 3.02	$ 2.05	$ 2.68	$ 1.83	$ 5.98	$ 2.72	$ 1.86	$ 2.47	$ 1.69
800	$ 9.54	$ 3.22	$ 2.19	$ 2.81	$ 1.92	$ 7.22	$ 2.92	$ 1.99	$ 2.61	$ 1.79
900	$ 11.35	$ 3.41	$ 2.30	$ 2.92	$ 1.99	$ 8.54	$ 3.10	$ 2.11	$ 2.73	$ 1.86
1,000	$ 13.33	$ 3.57	$ 2.41	$ 3.02	$ 2.05	$ 9.95	$ 3.27	$ 2.21	$ 2.83	$ 1.93

B. Transition to Higher E85 Volumes and Competition

A primary shortcoming of the EPA analysis and conclusions is their assumption that the historical pass-through observed in recent years will persist indefinitely, regardless of the level of RVOs. A simple economic analysis of the dynamics in this sector shows that would not likely be the case. Currently, RIN prices are roughly $0.80, and downstream margins on E85 appear to be in the vicinity of about 50%.

Suppose that the RVO was increased significantly. Refiners facing an increased renewable fuel obligation would increase the demand for separated RINs. Unless and until more ethanol is blended into fuels for end use by consumers, the price of RINs would also increase significantly.

Even without entry of new competition to sell E85, an E85 producer with market power will respond to those higher RIN prices. The ability to retain a portion of the RIN value created by E85 production serves as a net cost saving to the E85 blender (and to a much lesser extent, the E10 blender). All other things equal, an increase in that value is thus essentially a reduction in the cost of producing E85 (and in the cost of producing E85 relative to the cost of producing E10). Basic economic analysis shows that, even for a monopolist, a reduction in cost will lead to a decrease in price and an increase in quantity as long as the demand curve is downward sloping, which is not in doubt. In a market that is moderately, if not perfectly competitive, the same reduction in cost will lead to an even larger decrease in price and thus, an even larger increase in quantity.

Moreover, the high RIN prices would cause extraordinary profits for incumbent E85 blenders and/or retailers. While the RIN price increases would also slightly increase blender margins on E10, the E85 margins would grow much more quickly. Given the low barriers to entry into E85 production and distribution, the price of RINs can rise only so high before other blenders (who have heretofore focused solely on E10 production) would find entry into the E85 market profitable, realizing that RIN prices are so high that they could sell E85 at much higher discounts (*i.e.,* with a much higher pass-through rate) while still earning substantial profits because of the elevated RIN prices.

Once such entry occurs, or some incumbent blenders perceive a more profitable strategy involves discounting E85 to gain incremental volumes (thereby increasing the number of separated RINs for sale to upstream refiners), then larger E85 discounts would begin to emerge for retailers and ultimately FFV owners. While blender/retailer margins would likely fatten initially due to higher RIN prices, competition would quickly arise once it is clear that retaining the RIN value does not enable sufficient volume to satisfy the RVO, and entrants undercut high-margin incumbents in order to move volumes into the market to gain RINs. In turn, the higher discount to E85 would make it increasingly attractive to FFV owners facing the fuel decision at the pump; while a relatively small share of FFV owners may choose E85 at the pump when the discount is at its current below-parity rate of roughly 15%, the share of FFV owners choosing E85 is certain to increase as discounts cross the point of parity and hit 30%, 40%, et cetera. At this point a virtuous cycle can emerge where prices could fall dramatically and volumes expand significantly.

Eventually, entry into the E85 blending sector will reduce upward pressure on RIN prices and will result in a new equilibrium with higher levels of E85 consumption. So, it is entirely plausible that pass through of RIN value would start at or near the 50% level, as it currently stands, but move to 75% or higher levels once the higher volumes and more competition characterize the new market equilibrium.

A transition to a new market regime (e.g., RVOs well beyond the blendwall) is frequently characterized by transitory volatile and/or high prices that subside quickly into a new equilibrium level. A good recent example of this phenomenon occurred in California in late 2011, prior to the 2013 compliance year for the carbon cap-and-trade market. Figure 6 shows the price per metric ton of CO_2 equivalent ($/tonne) of California Carbon Allowances. Vintage 2013 allowances began trading on forward markets in late August 2011, and prices initially spiked to almost $24/tonne before trading between $12 and $19 per tonne through 2013. Since the beginning of 2014, most trades have been observed in a relatively narrow range of $12 - $13. This follows similar experiences in new allowance markets for SO_2, NO_x, and other CO_2 markets. Markets generally find an equilibrium level after a period of adjustment, and we would expect the RIN market to produce a similar pattern.

Figure 6: California Carbon Cap and Trade Prices, August 2011 – July 2016

Source: California Carbon Dashboard (http://calcarbondash.org/).

VI. Conclusion

We have shown that a much more price responsive demand relationship between the E85 discount relative to E10 and E85 volumes sold has a substantial influence on the RIN price necessary to achieve significantly expanded RVO targets. This relationship is not linear throughout a broad range of E85 price discounts, becoming particularly strong around the energy parity level where E85 and E10 are priced to reflect equivalent energy content. The EPA finding of a linear relationship between E85 discounts and volumes, while superficially consistent with recent observed data, cannot be relied upon as a reasonable method to extrapolate into greater E85 discounts and higher E85 sales volumes.

Although we agree that RIN value is not being fully passed through as E85 price discounts from the blender and/or retail stages in the supply chain, we believe that RIN pass-through may be modestly higher than EPA estimates, and that competitive pressures would increase pass-through percentages if higher volumes were mandated. In that regard, we disagree with Burkholder's conclusions regarding an absence (in his view) of longer run dynamics: "The data strongly suggest, however, that a significant portion of this RIN value is being, and likely will continue to be, withheld by E85 wholesalers and retailers in order to maximize their profits."[41] He does later suggest that changes would likely occur:

> *Over time, we believe that the RFS program – through the RIN price mechanism – can lead to E85 sales growth that accelerates at an increasing pace by encouraging infrastructure investment motivated by higher profit margins in the near term, and lower E85 retail pricing that results from increasingly competitive E85 markets in the long term.*[42]

However, this view does not reflect the very real potential for substantial near-term increases in E85 volumes with existing fueling infrastructure and FFVs already on the roads. Mr. Burkholder implies that significant expansions of E85 sales can only occur *after* short run supranormal profits will be used to fund infrastructure expansion, which *then* will lead to more E85 sales. This is a circular argument that underlies perpetual RVO set near the blendwall level, rather than setting RVOs beyond the blendwall and boosting RIN prices to levels where it is profitable to expand E85 volumes via discounted E85 prices leading to higher sales from existing stations to existing FFVs. As EPA seems to recognize (and as the Stillwater report concludes), current infrastructure does not seem to be limiting E85 consumption; rather it is E85 prices relative to E10 prices that currently impede higher E85 penetration into existing FFVs, which represents an enormous unrealized potential for renewable fuel expansion. The current RFS price mechanism – the RIN market – is designed precisely to reduce the effective price of E85. We find that RIN prices of $1 - $2 – depending on the pass-through rate and number of stations selling E85 – would support a substantial expansion of E85 and enable EPA to set the RVO for renewable fuel well above the proposed level.

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41 Burkholder, 2015, p. 10.

42 *Ibid.*, p. 13.

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Appendix A

E85 Demand Estimation

I. Description of Korotney's Analysis

We examined the various analyses conducted by David Korotney in his memorandum "Correlating E85 consumption volumes with E85 price" in support of his conclusion that the relationship between E85 price reduction (relative to E10) and E85 demand is linear. Ultimately, we find that Mr. Korotney failed to sufficiently investigate non-linear functional forms and his analysis did not fully capture the price responsiveness exhibited by consumers in available data. For those reasons, we do not find his resulting linear demand relationships a reasonable basis on which to estimate E85 volumes under various conditions.

A. State-Specific Regressions

Korotney runs linear regressions on data for 5 states: Minnesota, California, Iowa, New York, and North Dakota. The form of his equation is:

Gallons of E85 per month per station offering E85 = a × (E85 price discount) + b

This yields the following results, shown in Table A-1 with the Brattle replication shown on the right.[1]

[1] We use Korotney's data as reported in his Appendix Tables A-1 to A-13. Note that Korotney drops months in which E85 prices were collected on less than 5 separate retail stations for a given month and state, or less than 10 total price reports for a given month and state. We have applied the same screen before conducting the analyses we present here. We are unable to fully replicate the results of Korotney's linear regressions for Iowa and New York. For Iowa, Korotney Memo Table 1 suggests that Mr. Korotney uses 84 observations in his Iowa regression, but in the replication from his Appendix data we have 72 monthly observations. For New York, applying screens consistent with Mr. Korotney's Table 1, we exclude 50 observations from the analysis where he drops 48.

Table A-1: Replication of State Level Regressions

State			Korotney Results (Table 2)			Replication				
			Coefficient a	Constant b	R-Squared	Coefficient a	Constant b	R-Squared	MSE	Obs #
Minnesota	MN	estimate	12768	1031	0.28	12,765***	1,031.4**	0.279	718.02	72
		p-value	(p < 0.0001)	(p = 0.0205)		(1.896e-06)	(0.02040)			
California	CA	estimate	5392	7315	0.004	5,420.3	7,308.1***	0.004	2068.3	54
		p-value	(p = 0.6359)	(p = 0.0001)		(0.6338)	(9.274e-05)			
Iowa	IA	estimate	14164	2693	0.33	13,318***	2,594.3***	0.435	861.72	72
		p-value	(p < 0.0001)	(p < 0.0001)		(2.879e-10)	(3.282e-10)			
New York	NY	estimate	27046	2153	0.22	18,286**	3,461.3**	0.127	2330.2	33
		p-value	(p = 0.0047)	(p = 0.2103)		(0.04179)	(0.03693)			
North Dakota	ND	estimate	6134	-10	0.79	6,133.7***	-10.114	0.790	171.21	16
		p-value	(p < 0.0001)	(p = 0.9398)		(4.218e-06)	(0.9401)			

Mr. Korotney does not use this data to test for non-linearity, stating that the data available is "insufficient to determine whether or not E85 sales do in fact increase significantly when the price of E85 is less than E10 on an energy equivalent basis."[2] This is a testable assertion. Accordingly, we estimate variants on his regression, using the same data, experimenting with various non-linear functional forms, and also including variables to capture seasonal and annual effects. It is important to include these additional indicator or "dummy" variables to capture the effects of omitted variables whose absence might otherwise bias the results. For example, seasonal dummies can capture the effects of the summer driving season, and annual dummies will control for factors like the increase in the size of the FFV fleet over time. The majority of our regression results provide evidence that non-linear relationships tend to better explain the state data than the corresponding linear model.

We estimate three potential non-linear relationships, presented in Equation A-1 through Equation A-3 below, where Q_t represents the quantity of E85 sold per station (per month, based on this monthly data).

Equation A-1: Log-Level Specification

$$\ln Q_t = \beta_0 + \beta_1 * \left(\frac{P_{E10} - P_{E85}}{P_{E10}}\right)_t + \sum_{i=1}^{3} \gamma_i * Quarter_{it} + \sum_{j=2009}^{2013} \delta_j * Year_{jt} + \varepsilon_t$$

[2] David Korotney, "Correlating E85 consumption volumes with E85 price", EPA Air Docket EPA-HQ-OAR-2015-0111 ["Korotney 2015 Memo"], p. 13.

Equation A-2: Log-Log Specification

$$\ln Q_t = \beta_0 + \beta_1 * \ln\left(\frac{P_{E10} - P_{E85}}{P_{E10}}\right)_t + \sum_{i=1}^{3} \gamma_i * Quarter_{it} + \sum_{j=2009}^{2013} \delta_j * Year_{jt} + \varepsilon_t$$

Equation A-3: Quadratic Specification

$$Q_t = \beta_0 + \beta_1 * \left(\frac{P_{E10} - P_{E85}}{P_{E10}}\right)_t + \beta_2 * \left(\frac{P_{E10} - P_{E85}}{P_{E10}}\right)_t^2 + \sum_{i=1}^{3} \gamma_i * Quarter_{it} + \sum_{j=2009}^{2013} \delta_j * Year_{jt} + \varepsilon_t$$

With the exception of California, every state's data show evidence of a non-linear fit for the data. Presented below are the results of the best-fitting specification, as well as the results of the linear regression with quarterly and yearly dummies for each state. For each table, we also present the mean squared error in addition to coefficients and p-values. Measuring goodness of fit by mean squared error is necessary to compare the fit of the regressions using the transformed dependent variable, $\ln Q_{E85}$, to the fit using the untransformed variable, Q_{E85}.[3] The mean squared error measure suggests that the fit from at least one of the non-linear regressions exceeds that of the corresponding linear regression for 4 out of 5 states.

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[3] It is not valid to compare the R-squared from a regression using an untransformed dependent variable with the R-squared from a regression using a log-transformed dependent variable. Thus, in order to compare fit, the log-transform has to be reversed after the regression is estimated. Accordingly, after estimating either a log-log or log-level regression, we predict $\ln(Q_{E85})$, then take the anti-log, applying an adjustment to account for the log-normality of the transformed error term. The mean squared error measure can then be generated for all models; the mean squared error is the average of the square of the difference between the actual value and the predicted value resulting from a given regression model.

Table A-2: Minnesota Data, Linear vs. Log-Log Specification

Variable		Linear With Seasonal Effects	Log-Log With Seasonal Effects
E85 Price Reduction	estimate	11,228***	
	p-value	(9.234e-05)	
Ln(E85 Price Reduction)	estimate		0.7012***
	p-value		(2.105e-06)
Quarterly Dummies			
Q1	estimate	-667.29***	-0.2336***
	p-value	(4.277e-04)	(1.256e-04)
Q2	estimate	37.494	-0.01330
	p-value	(0.8266)	(0.8078)
Q3	estimate	266.95	0.07290
	p-value	(0.1269)	(0.1912)
Annual Dummies			
Year = 2009	estimate	-861.66***	-0.2551***
	p-value	(4.506e-04)	(7.345e-04)
Year = 2010	estimate	-667.13***	-0.1888***
	p-value	(0.002624)	(0.006842)
Year = 2011	estimate	381.65	0.1423*
	p-value	(0.1333)	(0.06764)
Year = 2012	estimate	-164.20	0.003579
	p-value	(0.5751)	(0.9683)
Year = 2013	estimate	-412.96*	-0.1291*
	p-value	(0.07494)	(0.08222)
Constant	estimate	1,676.2***	9.4060***
	p-value	(0.006876)	(0)
Mean Squared Error		473.98	465.31
Observations		72	72
F-Test for Seasonal and Annual Fixed Effects		0.0000	0.0000

Notes:

[1]: Log-log specification is detailed in Equation A-2.

[2]: Results reflect data spanning January 2009 through December 2014.

[3]: *** p<0.01, ** p<0.05, * p<0.1.

Using Mr. Korotney's Minnesota data, we find a log-log relationship between E85 price discount and quantity of E85 per station provides a slightly better fit to the data than the linear fit, also adjusting for seasonal effects. The seasonal and annual fixed effects contribute significantly to the fit of the regression and are jointly significant, suggesting that failure to control for these factors (as done in the EPA analysis) leads to biased estimates of the relationship.

Table A-3: Iowa Data, Linear vs. Log-Level Specification

Variable		Linear With Seasonal Effects	Log-Level With Seasonal Effects
E85 Price Reduction	estimate	9,637.8***	1.9062***
	p-value	(1.916e-06)	(2.257e-06)
Quarterly Dummies			
Q1	estimate	-361.89	-0.07570*
	p-value	(0.1018)	(0.08648)
Q2	estimate	838.24***	0.1596***
	p-value	(7.348e-04)	(0.001213)
Q3	estimate	844.43***	0.1758***
	p-value	(8.352e-04)	(5.133e-04)
Annual Dummies			
Year = 2009	estimate	-722.93***	-0.1585***
	p-value	(0.006603)	(0.003002)
Year = 2010	estimate	2.6842	-0.02427
	p-value	(0.9921)	(0.6519)
Year = 2011	estimate	597.60**	0.08159
	p-value	(0.02354)	(0.1171)
Year = 2012	estimate	-428.37	-0.1141**
	p-value	(0.1292)	(0.04426)
Year = 2013	estimate	-217.69	-0.07068
	p-value	(0.4024)	(0.1748)
Constant	estimate	3,081.1***	8.1348***
	p-value	(0)	(0)
Mean Squared Error		583.07	562.54
Observations		72	72
F-Test for Seasonal and Annual Fixed Effects		0.0000	0.0000

Notes:

[1]: Log-level specification is detailed in Equation A-1.

[2]: Results reflect data spanning January 2009 through December 2014.

[3]: *** p<0.01, ** p<0.05, * p<0.1.

Similarly for Iowa, we find a log-level specification fits the data moderately better than the linear fit with seasonal dummies. The seasonal and annual dummies are again highly significant, and the fit of both functional forms unsurprisingly improves considerably due to their addition. The linear specification without dummies in our replication results in an R-squared of 0.435; adding dummies to that regression improves the fit to an R-squared of 0.742, explaining over half of the remaining variation.

Table A-4: New York Data, Linear vs. Log-Level Specification

Variable		Linear With Seasonal Effects	Log-Level With Seasonal Effects
E85 Price Reduction	estimate	17,115**	3.8617***
	p-value	(0.03527)	(0.001943)
Quarterly Dummies			
Q1	estimate	-909.14	-0.2890**
	p-value	(0.2932)	(0.02684)
Q2	estimate	868.03	-0.03442
	p-value	(0.3774)	(0.8079)
Q3	estimate	936.73	0.03172
	p-value	(0.2791)	(0.7983)
Annual Dummies			
Year = 2009	estimate	-3,888.8***	-0.5351***
	p-value	(3.134e-05)	(6.158e-05)
Year = 2010	estimate	-2,453.4***	-0.2612**
	p-value	(0.004772)	(0.03188)
Year = 2011	estimate	608.86	0.2731*
	p-value	(0.5293)	(0.05972)
Constant	estimate	5,040.4***	8.2694***
	p-value	(6.809e-04)	(0)
Mean Squared Error		1228.3	1041.9
Observations		33	33
F-Test for Seasonal and Annual Fixed Effects		0.0000	0.0000

Notes:

[1]: Log-level specification is detailed in Equation A-1.

[2]: Results reflect data spanning July 2008 through August 2011. In our replication, 50 of 83 observations are dropped, consistent with the screen applied by Mr. Korotney.

[3]: *** p<0.01, ** p<0.05, * p<0.1.

Regressions using the New York data are shown in Table A-4. Comparing the mean squared error from the two regressions, we see that the unexplained variation after running the log-level specification with dummies is 15% less than the same measure using the linear regression with dummies.

Table A-5: North Dakota, Linear vs. Quadratic Specification

Variable		Linear With Seasonal Effects	Quadratic with Seasonal Effects
E85 Price Reduction	estimate	4,052.1*	-4,922.0**
	p-value	(0.05885)	(0.03843)
(E85 Price Reduction)^2	estimate		34,448***
	p-value		(6.443e-04)
Quarterly Dummies			
Q1	estimate	-222.19	-214.91
	p-value	(0.4006)	(0.1466)
Q2	estimate	112.64	52.703
	p-value	(0.5348)	(0.5901)
Q3	estimate	-45.501	-9.9344
	p-value	(0.7608)	(0.9015)
Annual Dummies			
Year = 2009	estimate	-229.16	-151.68
	p-value	(0.3327)	(0.2425)
Constant	estimate	509.56	939.91**
	p-value	(0.3810)	(0.01395)
R-Squared		0.888	0.971
Mean Squared Error		124.81	63.273
Observations		16	16
F-Test for Seasonal and Annual Fixed Effects		0.1417	0.0450

Notes:

[1]: Quadratic specification is detailed in Equation A-3.

[2]: Results reflect data spanning January 2009 through May 2010. In our replication, 17 of 33 observations are dropped, consistent with the screen applied by Mr. Korotney.

[3]: *** p<0.01, ** p<0.05, * p<0.1.

Using the North Dakota data, we find a significant quadratic relationship that explains 97% of the variation in the data, as measured by R-squared. Furthermore, the highly significant coefficient on the quadratic term is a strong indication that the true underlying relationship is non-linear.[4] Here, the individual quarterly dummies are not significant on their own, as measured by the p-value for each coefficient, but a joint F-test shows that they are jointly significant at the 5% level.

[4] Although the first-order coefficient is negative, the composite effect is positive for nearly the entire range of the observed data.

Using the California data, the non-linear specifications do not appear to fit the data any better than the linear specification. However, we find a very significant relationship between E85 price discount and E85 volume that is only apparent when accounting for seasonal effects.

Table A-6: California, Linear vs. Linear with Seasonal Effects Specification

Variable		Linear	Linear With Seasonal Effects
E85 Price Reduction	estimate	5,420.3	20,688***
	p-value	(0.6338)	(2.856e-04)
Quarterly Dummies			
Q1	estimate		-1,072.0***
	p-value		(0.002632)
Q2	estimate		249.53
	p-value		(0.4675)
Q3	estimate		-236.44
	p-value		(0.4840)
Annual Dummies			
Year = 2010	estimate		-2,901.1***
	p-value		(1.812e-08)
Year = 2012	estimate		1,687.6***
	p-value		(1.410e-04)
Year = 2013	estimate		1,328.7***
	p-value		(0.002214)
Year = 2014	estimate		2,081.4***
	p-value		(6.343e-06)
Constant	estimate	7,308.1***	4,861.0***
	p-value	(9.274e-05)	(1.063e-07)
R-Squared		0.004	0.866
Mean Squared Error		2068.3	759.07
Observations		54	54
F-Test for Seasonal and Annual Fixed Effects			0.0000

Notes:

[1]: Results reflect data spanning January 2010 through December 2014. In our replication, 6 of 60 observations are dropped, consistent with the screen applied by Mr. Korotney.

[2]: *** p<0.01, ** p<0.05, * p<0.1.

Removing the noise from seasonal variation and effects that appear to vary annually, the R-squared is improved from 0.004 to 0.866, which represents a dramatic increase in explanatory power, and the coefficient for E85 price reduction is large in magnitude, highly statistically significant, and much more precisely estimated than in the regression without controls. This stands in stark contrast to the counter-intuitive finding from the simple linear regression that there is no statistically significant relationship between E85 price discounts and volumes (an impression that is further reinforced from the graphic shown on page 6 of the Korotney memorandum), and provides a vivid reminder that simple linear models can provide misleading results when important variables are omitted. This is illustrated graphically below in Figure A-1. Data from each year are graphed in distinct colors, and for each year a separate regression line is displayed in order to show the strong relationships that exist within a given year's data. Note that the slope relating to each year of data is steeper than the slope of the overall relationship that Mr. Korotney finds with a simple linear regression over all observations. Failure to control for other drivers of sales volume dampens the relationship, making it appear that there is only weak price responsiveness in California. In reality, the data show that customers are very responsive to price once key seasonal and annual fixed effects are taken into account.[5]

These observations suggest that even if the relationship between E85 price discount and E85 sales volumes were linear in the data range observed, Mr. Korotney's analysis does not derive valid or reliable slopes and intercepts in his analysis. In addition, the individual state data ranges over different time periods, making interpretation of the aggregated composite results extremely problematic. Mr. Korotney takes the average of the Five States data linear regression results to derive the linear relationship that he scales to the national level using U.S. total E85 station counts. But since each of his individual state results are demonstrably not accurate, this averaging method does not provide an accurate basis for a representative national E85 volume per station result. We believe that a more sophisticated approach, applied on a longer time series data of a single state (we selected Minnesota, as described later) provides a more robust and reliable estimate of average E85 volumes sold as a function of E85 price discounts that can be scaled to the national level.

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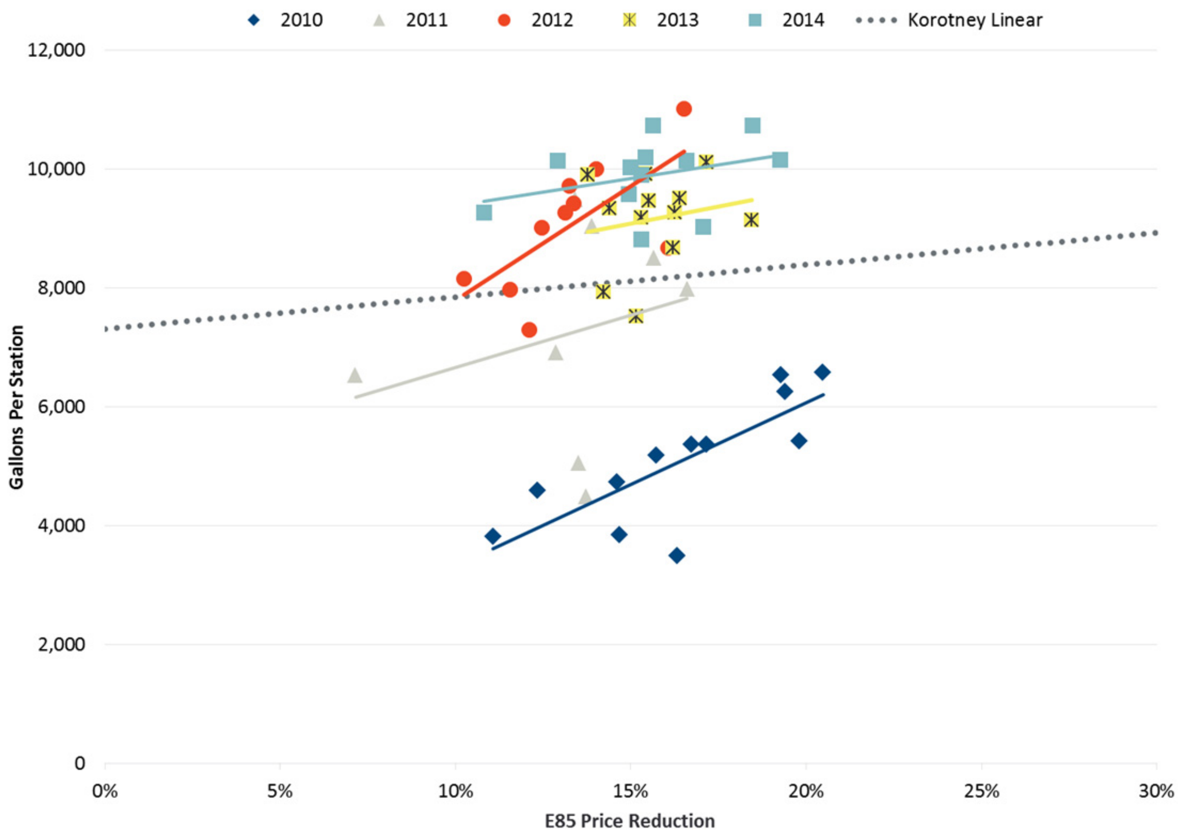
[5] For the purpose of illustrating the effect of omitted variables, the graphical analysis presented here focuses on one such set of factors, proxied for by the annual dummies. Our full regression model, presented in Table A-6, also includes seasonal (quarterly) dummies. Furthermore, our full regression model does not in fact estimate distinct slopes for every year. However, none of this changes the conclusions that can be drawn from Figure A-1. The fact that each of the individual slopes in Figure A-1 exceeds the slope estimated by Korotney clearly demonstrates that his failure to account for temporal variation (driven perhaps by increases over time in the number of FFVs on the road) results in an understatement of the price responsiveness of demand.

Figure A-1: California E85 Sales Volume as a Function of Price Reduction by Year



Note: This graphical illustration does not account for seasonal variation.

B. FUELS INSTITUTE AGGREGATE DATA

Mr. Korotney also generates a linear demand curve based on an aggregation of daily station-level data from the Fuels Institute. While we do not have access to these data and thus have not estimated our own demand functions with these data, the graphical example above presents a cautionary tale. Simply put, we cannot draw a meaningful conclusion on the correlation of these data as it does not account for station heterogeneity that might mask the true relationship, much in the same way that the aggregation of data across several years can mask the true relationship, as illustrated in Figure A-1. We are not arguing that data cannot be aggregated, but to the extent that factors other than price (such as differences across years, across states, or across E85 retail locations) influence sales volumes, any estimating equation has to take those into account in order to be reliable. The failure of Korotney to do so with the Fuels Institute aggregate data thus undermines any conclusion that might be drawn from those results. For this reason, we do not find the aggregate Fuels Institute data results to be meaningful.

C. STATION-LEVEL DATA

In an attempt to ascertain if non-linear relationships could exist between E85 price reduction and E85 demand, Mr. Korotney runs linear and quadratic regressions on daily data from the Fuels Institute for 6 individual stations, selected for having:[6]

- Highest E85 price reductions compared to E10
- Widest range of E85 price reductions compared to E10

Mr. Korotney's analysis of proprietary station-level data is not persuasive either, since (1) the analysis extends over a relatively short time period (19 months) which limits the extent to which the relationships can be adjusted for seasonal factors that, as the regression results discussed above show, tend to explain much of the variation in the data; (2) some of the graphics suggest outliers with small volumes that might mask some non-linearity (e.g., observations below 1,000 gallons per week on station #20); and (3) Mr. Korotney's only test for a non-linear relationship is to test the significance of a quadratic coefficient. While a significant quadratic relationship does suggest a non-linear relationship, as he shows for Station #40, this is but one of many possible functional forms that could characterize a non-linear relationship. In any case, we were able to discern non-linear relationships in the Five State data, as described above.

D. CONCLUSIONS ON FUNCTIONAL FORM

Mr. Korotney claims that his analysis "supports EPA's methodology of using a linear correlation between E85 sales volumes and the E85 price discount relative to E10 to estimate sales volumes of E85."[7] In analysis of other possible functional forms using Mr. Korotney's own data, we find that non-linear forms fit the data at least as well as Mr. Korotney's linear specifications (after appropriately adding seasonal and annual fixed effects), and generally produce a slightly better fit. Due to the uncertainty over precisely which non-linear functional form best describes the E85 price – sales volume relationship, we examine two alternate models based on Minnesota Department of Commerce data below.

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[6] Korotney 2015 Memo, p. 13.

[7] Korotney 2015 Memo, p. 16.

II. Minnesota Demand Estimation

We rely primarily on data from January 2009 through December 2015 from the state of Minnesota Department of Commerce.[8] The data contain monthly E85 sales volume (gallons), average E85 prices at stations, a count of the number of stations operating that offer E85, and 87 Octane average price data from the US Energy Information Administration (which are equivalent to Minnesota E10 prices, contrary to Mr. Korotney's concern).[9] The volume data from the Minnesota Department of Commerce is based on a survey of stations selling E85 and that survey has a very high response rate (recently, about 67%). The Minnesota Department of Commerce dataset remains the longest internally consistent data set on monthly E85 volumes and station counts of which we are aware. These data clearly reveal the negative correlation between E85 sales and the E85/E10 price ratio, as well as seasonality in E85 sales.[10]

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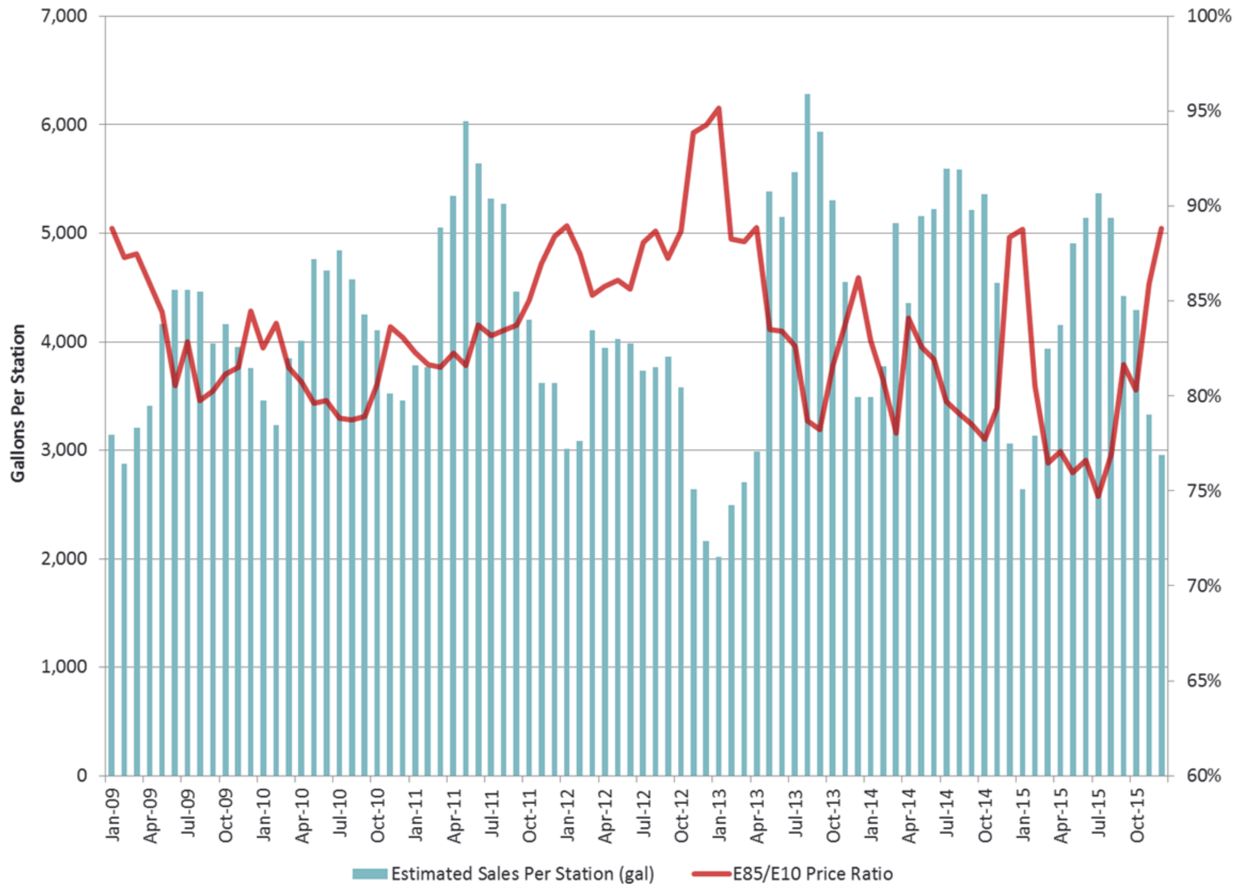
8 See, for example, the 2015 report available at: http://mn.gov/commerce-stat/pdfs/e85-fuel-use-2015.pdf.

9 The underlying data series for 87 Octane prices is "Weekly Minnesota Regular Conventional Retail Gasoline Prices" available at http://www.eia.gov/. Under current market conditions, the 87 Octane price is synonymous with E10 prices in Minnesota. The correlation between the Minnesota Department of Commerce reported 87 Octane prices and the E10 prices for Minnesota reported in E85prices.com data was 99%, making the data effectively identical. Thus Mr. Korotney's criticism of the E10 price data from Minnesota Department of Commerce is both incorrect and moot.

10 We do not use data available from Minnesota Department of Commerce before January 2009, consistent with data treatment in Philip Verleger, Jr., "The Renewable Fuel Standard: How Markets Can Knock Down Walls", January 2014, in order to reduce the influence of "early adopters" in 2007-2008. Annual Minnesota Department of Commerce E85 data goes back to 2000.

Figure A-2: Relationship between E85 Sales (gallons/station) and E85/E10 Price Ratio



Source: Minnesota Department of Commerce, Division of Energy Resources.

We find the period of data availability sufficient for finding statistically significant relationships. Of note, these data have been used in previous studies on the topic and seem generally accepted in the field.[11]

A. SPECIFICATIONS

We explore two specifications, similar to Equation A-1 and Equation A-2 provided above. In order to generate a negative demand relationship (i.e. the higher E85 prices, the lower demand), we frame the key independent variable as the price ratio between E85 and E10.[12] When the ratio

11 See, for example, Changzheng Liu and David L. Greene, "Modeling the Demand for E85 in the United States", Oak Ridge National Laboratory, September 2013.

12 This is equivalent to 1 minus the independent variable used in the Korotney analysis and in the analysis described above.

is 100%, E85 is priced the same as E10. When the ratio is around 78%, E85 is priced at energy parity with E10.

Equation A-4: Minnesota Log-Level Demand Specification

$$\ln Q_t = \beta_0 + \beta_1 * \left(\frac{P_{E85}}{P_{E10}}\right)_t + \sum_{i=1}^{11} \gamma_i * Month_{it} + \sum_{j=2009}^{2014} \delta_j * Year_{jt} + \varepsilon_t$$

Equation A-5: Minnesota Log-Log Demand Specification

$$\ln Q_t = \beta_0 + \beta_1 * \ln\left(\frac{P_{E85}}{P_{E10}}\right)_t + \sum_{i=1}^{11} \gamma_i * Month_{it} + \sum_{j=2009}^{2014} \delta_j * Year_{jt} + \varepsilon_t$$

As demonstrated in Table A-6 above, the seasonal and annual fixed effects make significant contributions to fit and are jointly significant, suggesting that their omission could bias the estimates of the coefficient(s) of interest. This is consistent with the well-documented cyclical trends in the motor fuel and E85 market and with the changes over time in demand and supply conditions. As the Minnesota dataset contains more observations than those used in the regressions described above, giving us additional degrees of freedom, we use monthly dummies rather than quarterly dummies to capture seasonal effects in the regressions that follow.

Our main conclusions from this analysis are: (1) monthly and annual dummies are highly significant and capture seasonal effects that increase the fit markedly, for both linear and non-linear specifications, and (2) the log-level and log-log specifications fit the data better than the linear specification, *with the same number of parameters*. As alluded to above, if one adds additional right-hand side variables to a given regression specification, the fit, which is typically measured by R^2, will tend to improve (and will always be at least as good). Accordingly, a more appropriate comparison of the fit of a linear regression with that of a regression where the dependent variable has been log-transformed is the mean squared error measure. With such a comparison, it is not the case that the fit is better because additional parameters have been added. Rather, it is simply a meaningful indicator that one functional form provides a better fit to the data than another. Since the goodness of fit is at least as good, and usually slightly better, the non-linear specification is preferred because it also reflects our intuition regarding consumer demand: at a certain level of E85 discount relative to E10, flex fuel vehicle owners will buy much more E85.

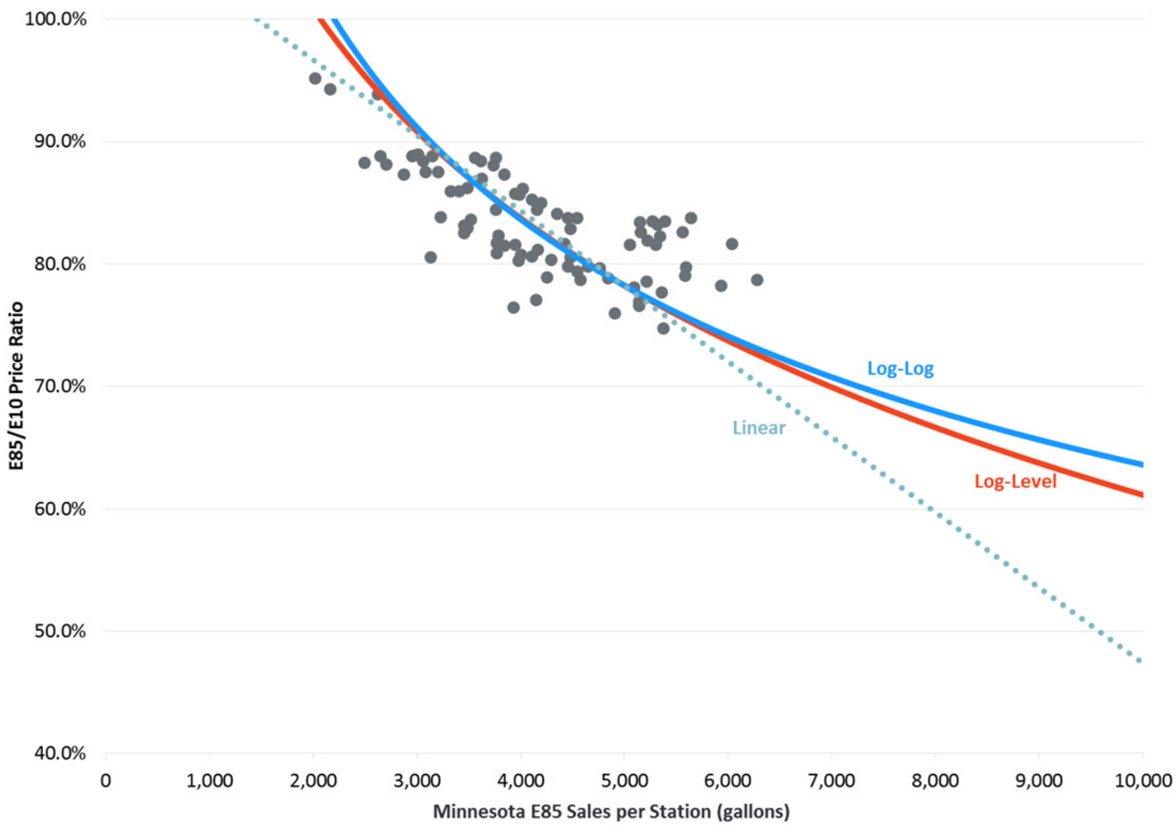
Table A-7: Minnesota Demand Curve Specifications

Variable	Linear with Seasonal Effects	Log-Level with Seasonal Effects	Log-Log with Seasonal Effects
E85/E10 Price Ratio	-14,742***	-4.0549***	
Ln(E85/E10 Price Ratio)			-3.3460***
Annual Dummies			
Year = 2009	220.09	0.08205**	0.08660**
Year = 2010	38.508	0.02857	0.03420
Year = 2011	1,050.5***	0.2717***	0.2774***
Year = 2012	550.79***	0.1669***	0.1643***
Year = 2013	873.65***	0.1936***	0.1946***
Year = 2014	699.75***	0.1723***	0.1767***
Monthly Dummies			
January	-224.86	-0.07163	-0.07206
February	-520.06**	-0.1386***	-0.1329***
March	37.185	0.005454	0.009842
April	203.32	0.05762	0.06291
May	864.60***	0.2002***	0.2064***
June	796.83***	0.1860***	0.1926***
July	850.98***	0.1913***	0.1958***
August	777.88***	0.1663***	0.1708***
September	421.46*	0.09797*	0.1039*
October	401.06*	0.1018**	0.1078**
November	127.62	0.04114	0.04413
Constant	15,648***	11.485***	7.4848***
Adjusted R-Squared	0.860		
Mean Squared Error	314.53	297.31	304.99

Note: *** p<0.01, ** p<0.05, * p<0.1

Using the regression results from Table A-7, we generate demand curves for Minnesota consumers in Figure A-3 below illustrating the predicted demand for E85 at certain price ratios relative to E10. The gray dots represent individual data points while the line and two curves illustrate the estimated relationships presented in Table A-7.[13]

Figure A-3: Minnesota Demand Estimation (with Price Ratio)



Note: Price Ratio is used in the regression, calculated as (E85 price / E10 price).

The presentation of Figure A-3 preserves the negative relationship between price and demand that is typical in a demand curve, i.e. a higher E85 price implies lower demand. Figure A-4 below presents the same results in the manner used by Mr. Korotney, framed in terms of price reduction percent rather than price ratio. The content of the figures is the same; they differ only in presentation.

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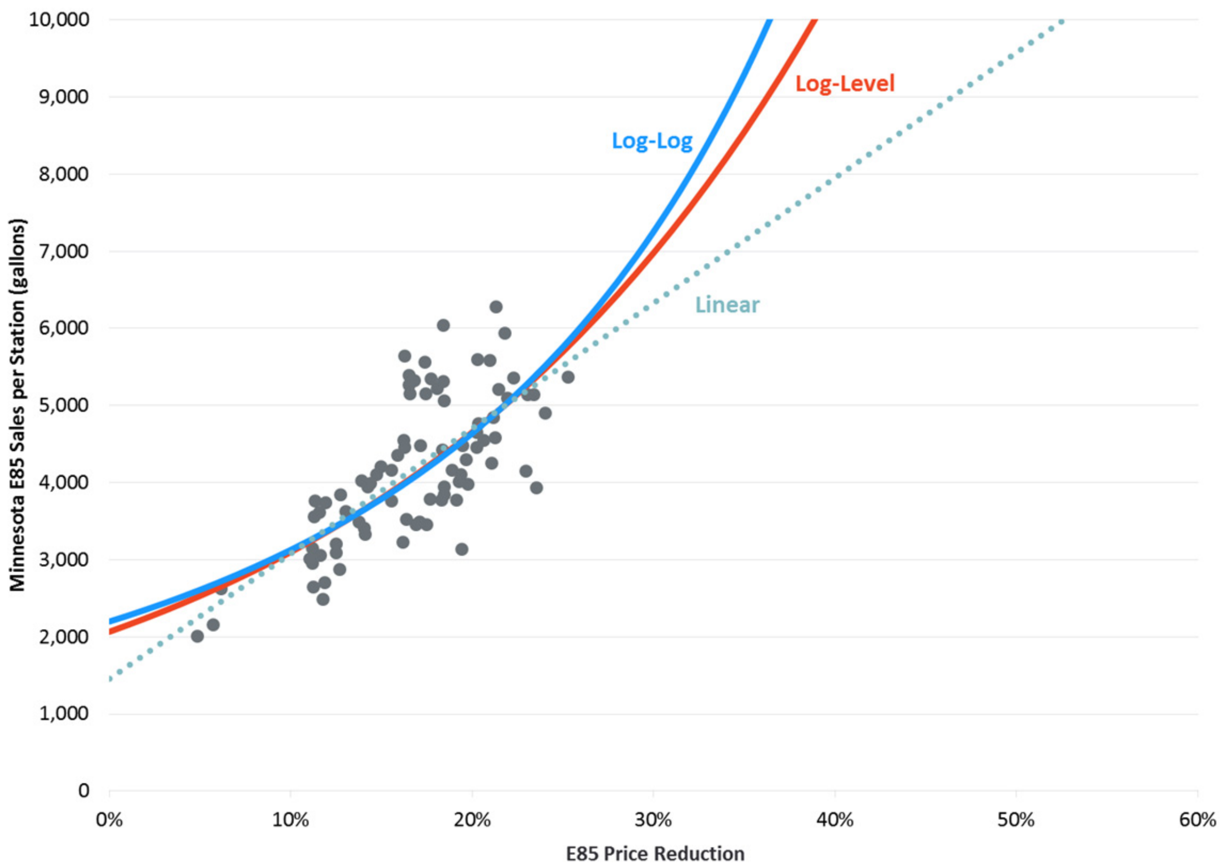
13 The individual data points in Figures 4 and 5 have not been adjusted to reflect the annual and monthly dummies. However, the relationships that have been graphed are based on the relationships estimated in Table 7, with the effects of the monthly and annual dummies averaged to calculate the intercept.

Figure A-4: Minnesota Demand Estimation (Korotney Price Discount)



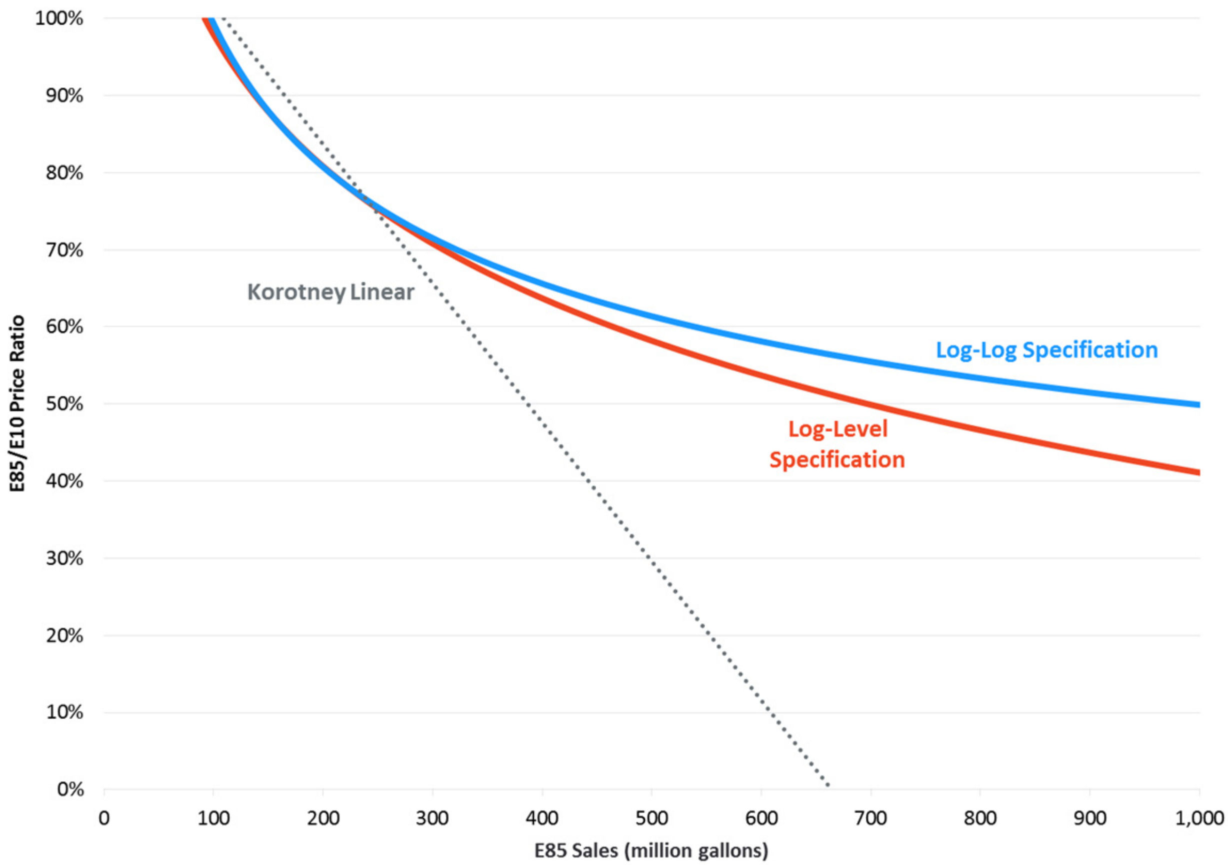
Note: Price Ratio is used in the regression, calculated as (E85 price / E10 price). The curve is presented with the Price Reduction calculated as 1 – (E85 price / E10 price).

In all E85 demand estimation discussed above or in the Korotney analysis, the range of values for which historical data are available is very limited, and generally includes few observations beyond the energy price parity point. Nonetheless, the functional form that is used in the demand curve estimation has important implications for out-of-sample predictions. As data at higher levels of the E85 discount accrue, estimates of the demand curve will improve and the appropriate functional form should become clearer. In the meantime, the log-log and log-level curves simply fit the data better than the linear relationship, and there are also strong intuitive reasons to prefer a log-log or log-level specification, as explained above and in the main report.

B. NATIONAL DEMAND IMPLICATIONS

Finally, the Minnesota results can be extrapolated to create a nationwide demand curve estimate.[14] Those results are presented in Figure A-5 for the case where 3,700 stations offer E85 in 2017.

Figure A-5: Nationwide E85 Demand Curve (3,700 Stations)



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[14] There are of course variations across states that limit the usefulness of extrapolating any economic relationship estimated at the state level to the entire United States. However, those concerns may be less critical in the case of Minnesota and E85. Minnesota is one of the most significant states in terms of E85 sales, and much of the nation's E85 sales volumes are concentrated in similar states within the same region.

Appendix B

RIN Price Pass-Through Analysis

In considering the relationship between RIN prices to E85 prices to use in our analysis, we evaluated two recent analyses.[1] In this appendix, we discuss those papers, and describe in greater detail our own empirical work in estimating a reasonable range of pass-through rates.

I. Burkholder Memo

In a November 2015 memorandum, Dallas Burkholder of the U.S. EPA estimates the share of the RIN value that is passed through to retail prices of E85. Using national average retail E85 and wholesale ethanol prices, Burkholder estimates the relationship between the retail markup on E85 and RIN prices, finding that a $1 increase in the RIN price increases the retail markup on E85 by $0.40.[2] Since it takes roughly 1.4 gallons of E85 to generate a D6 RIN, this implies that only $0.44 of each dollar in RIN value is passed through to consumers in the form of lower prices for E85.[3] As a control case, Burkholder also estimates the relationship between RIN prices and the E10 mark-up, finding no correlation between the D6 RIN price and the E10 retail mark-up.

In our own analysis, we adopt the basic structure of the Burkholder approach, but make some adjustments to address possible shortcomings in his analysis. The question of pass-through is complicated, and the variations we examine shed additional light on the level(s) of pass-through that should be relevant to setting policy in this context. The adjustments we make include: (i) the use of data covering a longer time period; (ii) use of data that correspond more closely to the experience in relevant geographic markets; and (iii) controlling for seasonality and other temporal variation in estimating pass-through.

A. Time Coverage of the Data

The data employed by Burkholder covered the period from January 2013 through July 2015. Burkholder appears to have intentionally limited his sample to start in January 2013, "when D6

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1 Burkholder, Dallas. "An Assessment of the Impact of RIN Prices on the Retail Price of E85." November 2015 ("Burkholder Memo"); Knittel, Christopher R., Ben S. Meiselman, and James H. Stock. "The Pass-Through of RIN Prices to Wholesale and Retail Fuels Under the Renewable Fuel Standard." NBER Working Paper 21343. July 2015 ("Knittel, et al.").

2 Burkholder Memo, pp. 8-9.

3 1-0.4*1.4 = 0.44. Incidentally, Burkholder calculates the cost of production of a gallon of E85 (which is comprised of 74% ethanol) by assuming that neat ethanol is mixed with E10 gasoline (which is comprised of 10% ethanol). However, in calculating the 1.41 adjustment factor he uses to translate his regression result to a pass-through rate, he fails to account for the fact that E10 also results in the production of RINs. A corrected adjustment factor of 1.35 implies a slightly higher pass-through rate of 46%.

RIN Prices first rose above a few cents per gallon."[4] His sample presumably ended due to data availability at the time he conducted his analysis.

While it wasn't exactly clear which data Burkholder used, we have estimated very similar results to his, using data available to us.[5] In particular, Columns 1-2 and 4-5 of Table B-1 provide a comparison of the Burkholder results from Figure 3 with the corresponding Brattle results. Our replication relied on data on retail E85 prices as collected by AAA and provided by Bloomberg, the Iowa wholesale price of ethanol as reported by USDA and provided by Bloomberg, and the national average wholesale price for regular gasoline as reported by the EIA. For RIN prices, we combined two price series. In particular, we utilized D6 RIN prices from Knittel, et al.'s replication dataset and supplemented this series with D6 RIN prices (provided by Bloomberg) to extend the time coverage. When the raw data were daily observations, we took simple averages of the observations within a month to convert them to monthly data.

Our results for the January 2013 to July 2015 time period are quantitatively and qualitatively very similar to those reported by Burkholder in his Figure 3. We obtain a similar pass-through estimate of 40%.

Table B-1: National E85 and E10 Retail Mark-Up Regressions

	E85			E10		
	Burkholder [1]	TBG Replication [2]	TBG Replication, using full time period [3]	Burkholder [4]	TBG Replication [5]	TBG Replication, using full time period [6]
D6 RIN Price Coefficient	0.3987	0.4292***	0.3178***	-0.0077	0.05224	0.04588
		(0.1010)	(0.06713)		(0.04559)	(0.03294)
Constant	0.6029	0.6833***	0.7408***	0.5522	0.7934***	0.7902***
		(0.05998)	(0.03705)		(0.02707)	(0.01818)
Observations	31	31	44	31	31	44
R-squared	0.2894	0.384	0.348	0.0001	0.043	0.044
Implied Pass-through	43.85%	39.55%	55.24%			

Notes:

The precision of the Burkholder estimates (presented in columns [1] and [4] are not provided. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

4 Burkholder Memo, p. 4.

5 On p. 4 of the Burkholder memo, EPA is described to have used pricing data from E85prices.com, while p. 8 states that E85 retail prices from OPIS were used.

There are two reasons to extend the data. The first is simply that additional recent data have become available in the 7 months since the Burkholder Memo was written, and can improve our estimates of current pass-through rates. Secondly, we believe there is value in exploiting the additional variation in RIN prices added to the dataset by including the period in 2012 (prior to the elevation in RIN prices) for which data are available. While the shorter period used by Burkholder focuses only on the relationship between changes in RIN prices and E85 retail markups observed *after* RIN prices began to rise, the relationship between the two variables as we left the period with low RIN prices is also informative to the question of pass-through.

Column 3 of Table B-1 presents the results when we estimate a Burkholder-style pass-through equation for E85 using national data similar to those he used, but extended to cover the full time period for which data are available. The data now cover August 2012 through March 2016, and the relationship changes noticeably when compared to columns 1 and 2. The relationship between RIN prices and retail markups is more precisely estimated, but lower in magnitude, and converts to a pass-through estimate of 55%, a full 15 percentage points higher than our Burkholder replication.[6]

It is also notable that corresponding regressions of the E10 markup, similar to that presented by Burkholder in his Figure 4, are consistent with his conclusion that there is no evidence of any strong relationship between RIN prices and E10 markups. The Burkholder results are provided in Column 4 of Table B-1, while our results, covering both the Burkholder period and the full sample, are presented in Columns 5 and 6 of Table B-1, respectively. These regressions rely on national E10 prices and are otherwise consistent with the approach taken by Burkholder.

B. National Data Vs. State-Level Data

The use of national data to capture pass-through dynamics in inherently regional markets may mask important variation in pass-through rates. Without knowing more about which data EPA used in regression analysis, it's not clear that we should expect national average retail prices—which presumably reflect substantial geographic variation in market dynamics—to provide a precise estimate of the RIN price pass-through, after controlling for state-level wholesale ethanol prices and wholesale gasoline prices. This is especially true since pass-through is widely believed to be a function of industry structure, which will also vary across geographic markets.

In order to explore the sensitivity of EPA's pass-through results, we estimate a state-specific variant of the full-sample results described above for two states (Minnesota and Iowa) with relatively well-developed E85 markets, while maintaining the same basic methodological

6 Here we have adopted Burkholder's formula for translating the relationship between RIN prices and the E85 retail markup. However, as noted above, this formula should be adjusted to account for the fact that E10 production also produces RINs. Accordingly, the results of the regression presented in Column 3 are actually consistent with a 57% pass-through.

approach. Where appropriate, we substitute more regionally granular data for that used by Burkholder. For example, rather than use a national average of E85 prices, we use state-specific averages for IA and MN from E85prices.com; the use of these data enables us to extend the period of our regressions. We make a similar substitution in calculating the cost of producing E85, otherwise adopting the equation and approach used by EPA on p. 6 of the Burkholder memo. In addition to using the national wholesale gasoline price series from EIA as used by EPA, we use two alternatives. The first is a monthly average of the daily Chicago spot price for CBOB.[7] The second alternative is a monthly average of the daily rack prices of CBOB at the largest city in each state (Minneapolis/St. Paul, MN and Des Moines, IA respectively). Use of these alternatives (*i.e.*, proxies for the price blenders paid for their blendstock) instead of a national wholesale regular gasoline price maintains consistency with the use of wholesale ethanol prices in that both reflect input prices for blenders. They also are more geographically relevant to those states that have significant E85 production and consumption.[8]

Table B-2 presents the results of our state-level regressions for Iowa and Minnesota using the various methods for constructing the dependent variable. While our results are consistent with Burkholder in finding that pass-through is incomplete, these results suggest, unsurprisingly, that there is heterogeneity in pass-through rates in different markets. Specifically, we see higher pass-through rates in Minnesota (ranging from 56-59%) than in Iowa (where the pass-through rate is 41-48%). Results using our preferred measure of feedstock prices (state-specific CBOB prices), are presented in Panel C. However, it is notable that the results in both states are robust to using nationwide wholesale gasoline prices (Panel A) or Chicago CBOB spot prices (Panel B) instead.[9] The precision of the RIN price coefficient estimates in the E85 regressions is comparable to those in Column 3 of Table B-1.

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7 CBOB stands for conventional blendstock for oxygenate blending, which in most states is the primary petroleum-based input to both E10 and E85.

8 We also considered using a Minnesota-specific wholesale ethanol price series in calculating the cost of E85 production for the Minnesota equation. However, the USDA price series for wholesale ethanol prices in Minnesota is only available beginning in July 2014. When both series are available, the Minnesota and Iowa price series are highly correlated (with a correlation coefficient of 0.99 when using averaged monthly prices, and 0.98 when using daily prices). Accordingly, we use the Iowa wholesale price series for ethanol in constructing the dependent variable for the Minnesota equation as well.

9 When transforming the estimated coefficient on RIN prices to a pass-through rate, we use a different adjustment factor for regressions based on CBOB prices, to reflect the fact that unlike E10, production of CBOB does not generate any RINs.

Table B-2: E85 and E10 Retail Mark-Up Regressions, Iowa and Minnesota

	E85		E10	
	Iowa	Minnesota	Iowa	Minnesota
	[1]	[2]	[3]	[4]
US Wholesale Gasoline [A]				
D6 RIN Price Coefficient	0.4097***	0.3107***	0.1465***	0.1390***
	(0.06542)	(0.08027)	(0.04227)	(0.05141)
Constant	0.4793***	0.5486***	0.6208***	0.6733***
	(0.03260)	(0.04000)	(0.02107)	(0.02562)
Observations	54	54	54	54
R-squared	0.430	0.224	0.188	0.123
Implied Pass-through	42.30%	56.24%		
Chicago CBOB [B]				
D6 RIN Price Coefficient	0.3879***	0.3070***	0.08396**	0.06725
	(0.06439)	(0.07595)	(0.04144)	(0.04534)
Constant	0.5193***	0.5854***	0.6868***	0.7411***
	(0.03320)	(0.03916)	(0.02137)	(0.02338)
Observations	57	57	57	57
R-squared	0.397	0.229	0.069	0.038
Implied Pass-through	47.58%	58.51%		
Regional CBOB [C]				
D6 RIN Price Coefficient	0.4378***	0.3072***	0.2567***	0.06791**
	(0.06032)	(0.07495)	(0.07600)	(0.02784)
Constant	0.4579***	0.5543***	0.4743***	0.6335***
	(0.03110)	(0.03865)	(0.03919)	(0.01435)
Observations	57	57	57	57
R-squared	0.489	0.234	0.172	0.098
Implied Pass-through	40.84%	58.49%		

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

Again, we have also included regressions where the E10 markup is the dependent variable. Here, we have used state-level E10 retail price data from E85prices.com, and have used the same set of alternate input prices that were used in the E85 markup regressions described above. In general, our results are broadly consistent with the finding of no relationship between RIN prices and E10 markups. They do generally imply a higher correlation between RIN prices and E10 retail mark-ups than in Columns [4]-[6] of Table B-1, which we will explore in further detail in the subsequent section.

C. Seasonality

Finally, consistent with the discussion and conclusions in Appendix A, we also estimated variants of our preferred regressions in which we include month and year indicator variables to capture the effects of seasonality and other longer-term trends that may be correlated with variation in RIN prices and margins, thus influencing our resulting coefficient and pass-through estimates. Burkholder's decision not to include adjustments for seasonality is one major difference between his empirical work and the work of Knittel, et al., which we discuss in greater detail below. Comparing Column 1 from Table B-3 with the Column 1 from Table B-2 (Panel C), we see that the inclusion of controls does not have a significant effect on the E85 pass-through estimates in Iowa. However, in Minnesota, the inclusion of year and month dummies significantly increases the E85 pass-through estimate. In columns 3 and 4, we see that after including year and monthly dummies, there is no evident relationship between RIN prices and E10 mark-ups, consistent with the Burkholder analysis.

Table B-3: State-Level Regressions of E85 and E10 Retail Mark-Ups, with Monthly and Annual Controls

	E85		E10	
	Iowa [1]	Minnesota [2]	Iowa [3]	Minnesota [4]
D6 RIN Price Coefficient	0.4307***	0.2555**	-0.002880	0.03814
	(0.1071)	(0.1182)	(0.1348)	(0.05639)
Constant	0.4090***	0.4782***	0.4895***	0.6066***
	(0.09407)	(0.1038)	(0.1184)	(0.04951)
Observations	57	57	57	57
R-squared	0.715	0.663	0.539	0.345
Implied Pass-through	41.80%	65.47%		

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

D. Conclusions

Our analysis generates results that are *qualitatively* consistent with the conclusions reached by the EPA with respect to pass-through – RIN price values are only partially passed through by blenders to E85 retail prices, and do not appear to have an economically or statistically significant bearing on E10 prices. However, after addressing several issues in the data and specification used in the Burkholder Memo, we find evidence that under certain conditions, historical pass-through rates may be much higher than the EPA analysis concluded. Notably, our preferred specification, using a longer time series, state-level price data, and monthly and annual dummies, demonstrates that historical pass-through rates may be as high as 65% in states with better-developed E85 markets like Minnesota.

II. Knittel, et al.

Before undertaking our own empirical analysis, we also considered the empirical work presented in Knittel, et al. Using national data and an alternative methodological approach, they also undertake empirical work intended to ask slightly different, but closely related questions. Specifically, they estimate the effect of RIN prices on the retail E85-E10 spread, in addition to estimating the effect of RIN prices on the spread between the wholesale prices of various RIN-obligated and non-obligated fuels. In contrast with the Burkholder results, and with the Brattle results presented above, they find the pass-through of RIN prices to the E85-E10 spread to be either 30% (before adjusting for seasonality) or zero (after adjusting for seasonality). Their regressions use daily data covering the period from January 1, 2013 to March 10, 2015, and they use retail gasoline and E85 prices from the American Automobile Association (AAA) as provided by Bloomberg. Their regressions take the following general form:

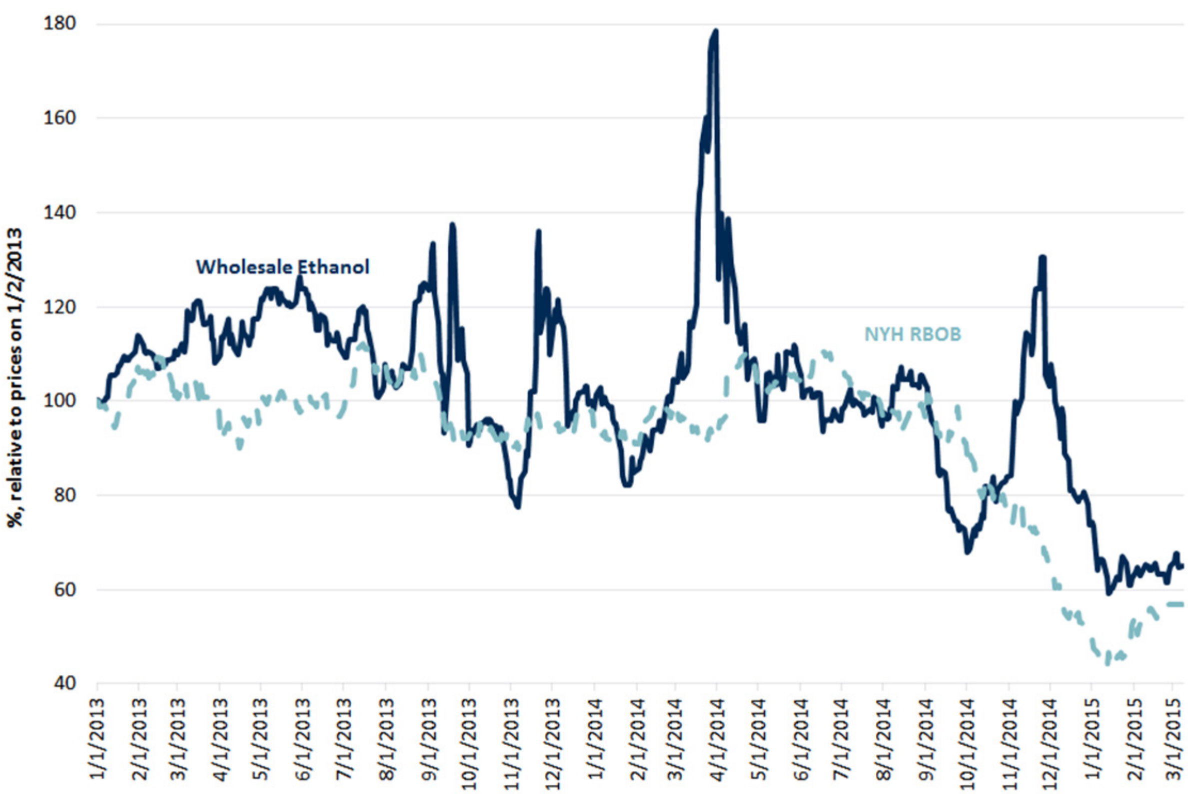
$$(P_{E10} - P_{E85})_t = \beta_0 + \beta_1 (RIN_{E85} - RIN_{E10})_t + \gamma_t + e_t$$

where P represents the retail price per gallon of the respective fuel, RIN represents the net RIN obligation associated with a gallon of each fuel, γ is a vector of seasonal controls, and e is the error term. β_1 is the coefficient of interest. While we have not replicated or extended the Knittel, et al. results, we do note certain features of their data and specification that may represent shortcomings of their approach and that may partially explain the difference in their results relative to those discussed above.

First and perhaps foremost, there appears to be a significant omitted variables problem. Other than seasonal variables, the only explanatory variable included on the RHS of the regression is the net RIN obligation, which is equal to the difference between the net RIN value created when producing a gallon of E85 and the (negative) net RIN value created when producing a gallon of E10. The obvious omission from their specification is a measure of input prices for the two fuels, which vary over time. This is appropriate when estimating the spread between the wholesale prices of two fuels for which the primary material input is crude oil (for example gulf diesel and gulf jet fuel, as in the first column of their Table 2). In that instance, the primary determinant in the eventual wholesale price of each fuel will be "differenced out," and there should be no effect on the results from failing to include input prices.

However, in the case of the E85-E10 spread, the respective fuels are very different in composition. E85 is comprised, on average, of 74% neat ethanol and 26% of either RBOB or CBOB. However, regular gasoline (E10) is comprised of 90% RBOB or CBOB and only 10% ethanol. To the extent that movements over time in the prices of these two feedstocks vary, those differences (or equivalently, the levels of the two prices) are likely an important determinant of the retail price spread between E85 and E10. In particular, wholesale ethanol prices are much more volatile over the relevant period than RBOB prices, as is evident from Figure B-1. Failure to account for the corresponding differences in the input costs of the feedstock to the two fuels is likely to result in a biased estimate of β_1 (the effect of RIN prices on the retail price spread).

Figure B-1: Wholesale Ethanol and RBOB Price Movements



Source: Knittel Data, from Bloomberg

A second possible issue with the Knittel, et al. analysis is the use of national data. As described above, using national data may mask significant geographic heterogeneity in retail prices and retail price spreads. While retail gasoline prices in different geographic markets will tend to be highly correlated, there are nonetheless differences in their movement over time. National price averages such as the indices calculated by AAA necessarily involve some weighting scheme. Given the differences in the geographic distribution of E85 sales (which are heavily concentrated in Midwestern states such as Minnesota and Iowa) and retail gasoline sales (which are closely related to population and are thus more highly concentrated in states such as California, Texas, and Florida), the weighting schemes used in the two measures may differ significantly. Accordingly, the economic meaning of a national retail price spread is unclear. A more systematic analysis would require access to *daily* state- or region-specific data on retail prices of

E85 and E10, as well as blendstocks, which are not publicly available. This may have driven the data choices made by Knittel, et al.

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