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Charging into the Blend Wall: Conjoint Analysis of Consumer Willingness to Pay for Ethanol Blend Fuels

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Francisco X Aguilar and Wyatt Thompson

Abstract

Ethanol use in the U.S. rose sharply in recent years due to public policy and a spike in petroleum prices, and remains high. Public support for ethanol includes mandated minimum levels of use nationwide. However, rather little is known about consumer demand for ethanol and much less about demand by type of blend and ethanol source. We used trial survey data and conjoint analysis to overcome the lack of historical data on consumers' preferences for ethanol blend fuels. Preliminary findings based on responses from vehicle drivers in Missouri suggest that price is the primary factor behind fuel preferences. The disclosure of ethanol originated from woody feedstocks had a significant effect on preferences *ceteris paribus*. Ethanol blends of 20 percent had a negatively non-significant statistical effect compared to no-ethanol fuels or those with a 10 percent content. These findings will be tested using different models expanded to a nationwide pool of motor vehicle drivers.

Keywords: Ethanol blend fuels, consumers' willingness to pay, choice-based model

1. Introduction

The production of ethanol as a vehicle fuel has over 30 years of history in the U.S. Tyner (2008) suggests that the Energy Policy Act of 1978 was the first public policy to launch the U.S. ethanol industry by proving federal subsidies. Most recently, the Energy Policy Act of 2005 set a mandatory renewable fuel standard that requires the use of at least a certain amount of biofuels (Figure 1). The Energy Independence and Security Act (EISA) of 2007 increased the use mandate to 36 billion gallons of renewable fuels by 2022 and required that at least 21 billion gallons must be advanced biofuels (Public Law 110-140). Ethanol made from sugar cane can help to meet the advanced biofuel mandate, but at least 16 billion gallons must be comprised of cellulosic biofuel by 2022. The renewable fuel standard for 2010 requires using at least 12.95 billion gallons of renewable fuels of which 950 million must be categorized as advanced biofuels in 2010 (40 CFR 80). Although for this year the original EISA targets indicated 100 million gallons of cellulosic biofuels should be produced, many of the cellulosic biofuel production projects that served as the basis for the original targets have been put on hold, delayed, or scaled back. Therefore, the U.S. Environmental Protection Agency (EPA) used its discretion to waive the cellulosic biofuel mandate (40 CFR 80).

While federal mandates have and will continue to change the quantity and composition of biofuels sold in the U.S., the use of renewable fuels, nonetheless, faces significant challenges. As discussed by Painuly (2001), extensive adoption of renewable energies can be halted by cost-effectiveness, technical and market barriers such as “inconsistent pricing structures, institutional, political and regulatory barriers, and social and environmental barriers” (p. 75). Among various social, cultural and behavioral barriers, Painuly (2001) highlights the potential lack of consumer and social acceptance for a renewable energy product.

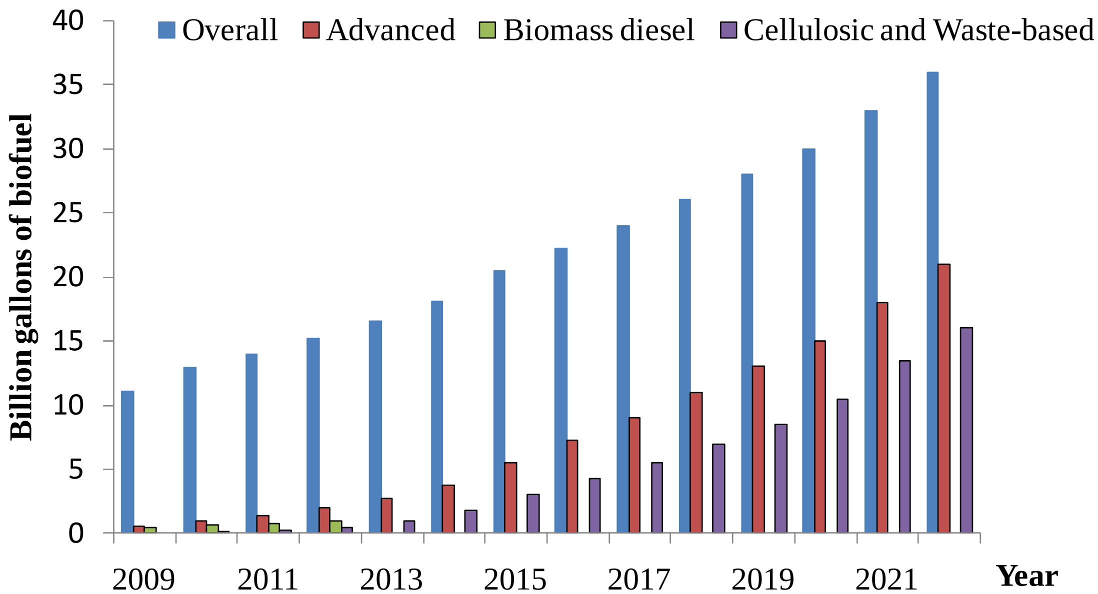

Figure 1. EISA biofuel use mandates.

Source: mandate levels are directly from the legislation where it specifies that biomass-based diesel must not be less than 1 billion gallons after 2012 (Public Law 110-140). Note: the mandates are nested, not independent (see Thompson et al 2009).

Federal support can help overcome economic barriers and catalyze the development of innovative biofuel conversion technologies and mandate the use of renewable as stipulated on the EISA. However, little is known about U.S. consumers' attitudes and acceptance of ethanol blend fuels use in motor vehicles. Some observers predict a looming *blend wall*, a limit to short-run expansion in ethanol use once easy market opportunities are exhausted. According to this theory, consumer demand tapers off quickly as only very low prices will induce consumers to use more ethanol. Expectations of rising biofuel use beyond this blend wall require the empirical estimation of how low prices must go before consumers are willing to buy high-ethanol blends (e.g. E85 with up to 85% ethanol).

This question is not an easy one to address in part because the relationship between ethanol and gasoline prices is a complicated one (Figure 2). The relevant characteristics of demand for motor fuels have changed over time. Following Westhoff et al (2007), the small volume of biofuels historically available was used as a complement to gasoline, a form of use that exploded due to regulatory changes in 2006, but further expansion in ethanol use must now be for its ability to substitute for gasoline. Thus, whereas the rack price of ethanol might once have had a premium relative to gasoline, at least before adjusting for the tax credit, the price in the future is more likely to be dictated by the marginal use. If the energy equivalence of ethanol relative to gasoline is about two-thirds and if this is adopted as a measure of substitutability, then the ethanol price might be expected to be about two-thirds of the gasoline price in order for consumers to adopt it widely.

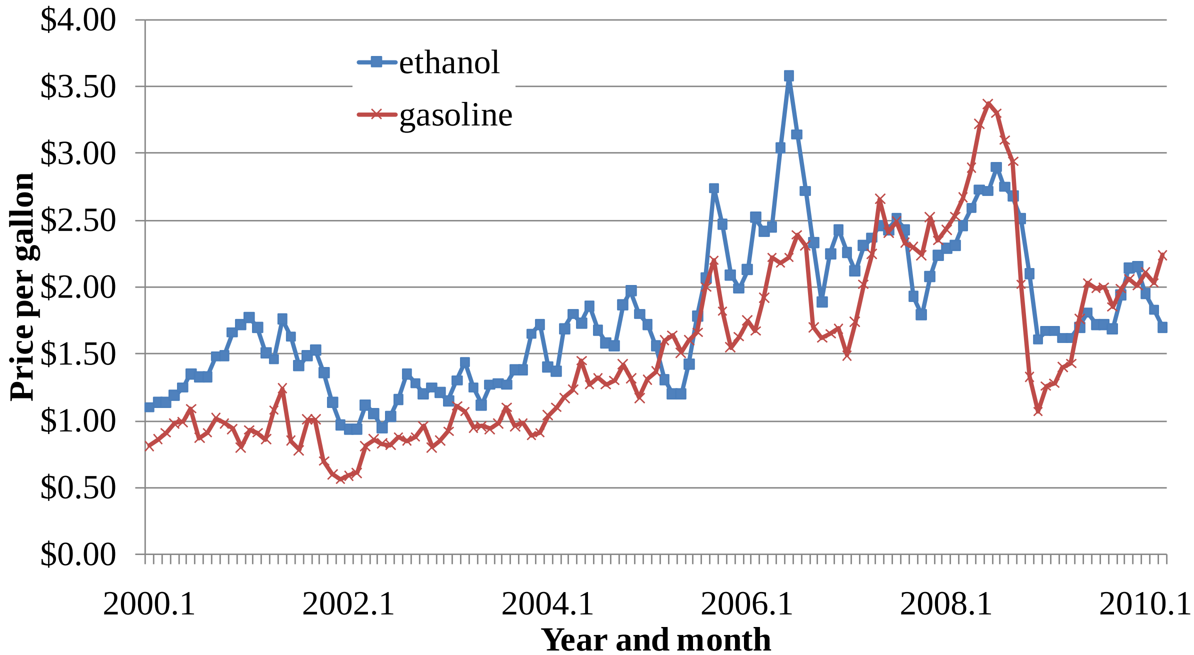

Figure 2. Ethanol and gasoline prices per gallon, rack rates.

Source: Nebraska Energy Office (2010).

To get a better measure of the prices to consumers, the rack price of ethanol can be reduced by the tax credit and compared to the gasoline price. (This comparison does not take rack-to-retail margins into account.) The rack price of ethanol less tax credit varies relative to the rack price of gasoline at Omaha varies, but the ethanol price less tax credit rarely falls below two-thirds of the gasoline price. One exception is in early 2010, when the ratio declined to 65 percent by March, the most recent data available at the time of writing. Some observers suggest that atypically cheap ethanol relative to gasoline indicates that the market has hit the blend wall. Their reason is that the marginal use of ethanol is more likely to be in a high-blend fuel, namely E85, so the price must be low to induce consumers to buy the fuel. At the same time, ethanol production and imports approach 10 percent of total motor fuels supplied to the U.S. (Figure 3) – the natural limit to the extent of the E10 market before additional ethanol sales must be in E85. At the same time, the growing mandates require that more and more ethanol will be sold in the U.S. in the coming decade.

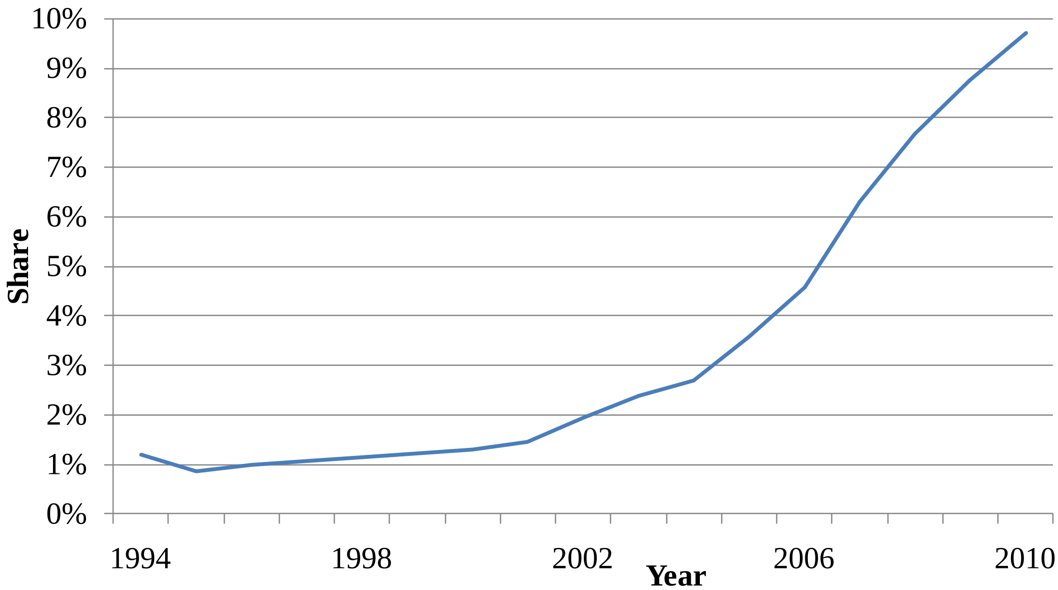

Figure 3. Ethanol production plus imports relative to total motor fuel supplied.

Source: EIA (2009) for1994-2009 data and FAPRI (2009) for 2010 estimates.

A key challenge to assessing what will happen as ethanol mandates expand is that there are few historical data because the increase in ethanol use has been sudden and sudden, and its role in the market has changed (Westhoff et al., 2007). Consequently, many researchers assume that ethanol demand is perfectly elastic at a price that reflects its energy equivalent to gasoline, with or without some additional premium, in the long run (de Gorter and Just, 2009; Tyner and Taheripour, 2008). According to this line of reasoning, consumers would be willing to replace all gasoline with ethanol as long as doing so lowers the cost per mile driven. Alternative assumptions about ethanol expansion beyond E10 use are typically based on some assumption of a finite elasticity of substitution (Thompson et al., 2008) or some “bottleneck” costs (Tokgoz et al., 2007). Nevertheless, assumptions about consumer behavior cannot be based on observed behavior because there are few data to indicate general consumer willingness to buy ethanol in higher blended fuels (e.g. E20, E85) which is and has been a boutique, not widely used fuel.

One way forward to estimate potential demand for ethanol fuel blends higher than the almost ubiquitous E10 is to draw conclusions from stated preferences elicited through consumer surveys. Roe et al. (2001), Zarnikau (2003), Bergmann et al. (2006) and Borchers et al. (2007) evaluated consumer willingness to pay (WTP) for renewable energy. Bunch et al. (1992) estimated consumer preferences for fuels in California using a discrete choice stated preference survey. The motor vehicle fuel attributes tested by Bunch et al. (1992) included price per gallon, distance range of a full tank, pollution relative to a 1991 car, and geographic availability. Two profiles analyzed with a binomial logit model using fuel-specific attributes, and segmentation variables based on household information and type of vehicle to be purchased were used by Bunch et al. (1992). More germane to our study, Petrolia et al. (2010) and Bhattacharjee et al. (2008) used survey data to estimate WTP for ethanol fuels. However, their approach was not sufficiently informative for purposes of assessing the blend wall. First, the Petrolia et al. study included a high ethanol fuel choice (E85), but Bhattacharjee et al. paper did not. Second, Petrolia’s elicitation question presumed ownership of an E85-ready vehicle, thus, not allowing assessment of consumer willingness to buy E85 and the required flex vehicle. Third, the surveys were conducted long before the fuel versus food debate played throughout the media, so it might not be representative of current or future consumer behavior. Fourth, methods of estimation did not allow assessment of what factors explain consumer WTP, so the results cannot be used to understand the fundamental forces behind ethanol demand. Lastly, their elicitation instrument was univariate (single response) and lacks the actual multidimensional nature (e.g. price, energy content, ethanol blend) of fuel purchases that can be incorporated in a conjoint analysis (CA).

This paper reports results of our preliminary study. The goals of our research were to:

1) Explore U.S. consumers' perceptions of biofuels as a first step towards identifying potential social barriers to the adoption of biofuel blends;
2) Determine the importance of selected biofuel attributes to consumer's likelihood to purchase ethanol blends; and
3) Evaluate the effect of ethanol content on consumers' choice preference for renewable fuels.

At this point, our work is based on a trial survey. Findings at this point should be taken as indicative of the nature of the research rather than definitive results. Follow up work discussed in our concluding section outlines the next steps we foresee in order to provide the scientific community with better estimates of consumer demand and to generate results that will be of use to decision makers who need to better understand the shape of consumer ethanol demand when markets are balancing at as yet unobserved quantities.

2. Theoretical Framework, Data Collection and Analysis

The analysis of consumer preferences was based on a random utility model (RUM). Under RUM, a consumer maximizes a utility function that is comprised of a deterministic component and a set of unobservable variables that introduce a random error element (Hanemann, 1984). Our application of the model used CA to determine the importance of different attributes when purchasing fuels. CA is based on the premise that consumers can judge the value of a collection of products described by different attributes that make up product profiles, and choose the one generating the greatest utility (Green and Srinivasan, 1978, 1990). CA helps determine a set of partial partworths that identify the relative importance that consumers place on each particular fuel attribute and allows the elicitation of product attributes not currently available in the market (Louviere and Hensher 1983). Such an approach is necessary not only for ethanol blends not permitted at present (e.g. E20), but also E85 which is not universally available and, as well, cannot be purchased by most consumers because they do not have flex fuel vehicles that can use this fuel. In the present study, consumers were assumed to choose the type of fuel that provided the greatest level of utility and, thus, was their selection in a discrete-choice scenario. We relied on the application of a forced-choice task with a *status quo* option to derive consumers' preferences using a conditional logit model. The status quo option is analogue to an opt-out option from ethanol blend fuels (i.e. a motor vehicle fuel not containing ethanol).

The trial survey data were collected in April 2010 and based on answers to the choice task question. The choice question was developed according to the following methods. First, the types of fuels presented to study participants were defined by specific profiles. Biofuel profiles were generated and matched in pairs plus a third "*status-quo*" option following an orthogonal design (Adamowics et al. 1998, Louviere et al., 2000). Profile attributes captured price, ethanol content, ethanol feedstock information and octane level. An orthogonal design allows the detection of statistically significant effects possible using small samples, as it reduces the standard errors of estimated coefficients (Ewing and Sarigollu 1998). The levels for price (expressed in dollars per gallon) were $2.00, $2.25 and $2.50; levels for ethanol content were 10, 20 and 85 percent, categories of ethanol origin included *no information* disclosed, *corn-based*, and *wood-based* (for cellulosic) ethanol. Energy content was identified at 89 minimum octane for E10 and E20 blends and 105 minimum octane for E85. During the selection of different attribute levels it was critical to ensure that no attribute's range was too wide as to dominate the choice process (Eagle 1988). Price is a common attribute that may dominate the selection process if presented in excessive wide ranges, resulting in only price being estimated as a factor behind consumers' choice. For each pair of renewable fuel profiles a third option was included which represented a *status quo* option or a gasoline with 0 percent biofuel content and 87 minimum octane.

Survey participants were presented with the following scenario: "*Your motor vehicle is running out of gas and you stop at the only available gas station where the only fuels available are the ones listed below. Your vehicle can use any of the fuels listed below. Which one would you choose*?" and asked to select one. Respondents could not decline all three alternatives presented to them. The reasoning for the use of a forced-choice task is the implication that motor vehicle ownership (unless a vehicle runs 100% on electricity) requires purchasing fuels. Figure 4 shows one of the scenarios presented to study participants. Each participant provided responses to three different choice tasks following a fractional sampling structure.

	Fuel 1	***Fuel 2***	***Fuel 3***
Price/gallon:	$2.25	$2.25	$2.50
Ethanol content:	10%	10%	0%
(minimum octane)	(89)	(89)	(87)
Ethanol source:	Corn-derived	Wood-derived	Not applicable
Your choice →	❒	❒	❒

Figure 4. Example of choice-task instrument.

Data collected in addition to the choice instrument include socio-demographic information (e.g. age, gender, annual income), number of vehicles per household, primary vehicle-type (e.g. conventional, hybrid, flex fuel), average number of miles driven per year. A pre-test of the CA instrument with 20 individuals meeting our sampling framework was conducted to obtain feedback from fuel consumers. A list of constructs used to explore perceptions towards biofuels was adapted from Petrolia et al. (2010). Prior to asking preference questions and the choice-task, participants were presented with the following definition adapted from the U.S. Department of Energy: "*Ethanol is a renewable fuel made from various plant materials, which collectively are called "biomass." Ethanol contains the same chemical compound found in alcoholic beverages. Nearly half of U.S. gasoline contains ethanol in a low-level* *blend to oxygenate the fuel and reduce air pollution. Ethanol is also increasingly available in E85, an alternative fuel that can be used in flexible fuel vehicles*."

Survey instruments were disbursed at the local Missouri Department of Motor Vehicles office following methods similar to Borchers et al. (2007). Data were also collected at a recreational center owned by the City of Columbia, MO. Data were analyzed using a conditional logit model (McFadden, 1974, 1986). DMV and Recreation center responses were pooled for the analysis. The dependent variable in the model was a binary response (1= alternative chosen, 0= otherwise). Price and ethanol content were set as continuous variables. Octane and ethanol source information were analyzed as categorical variables. An alternative specific coefficient was included to capture the unique attributes of the *status quo* option (0 percent ethanol and 87 octane level).

3. Results and Discussion

A total of 102 responses were collected with a perfectly even distribution between male and female respondents. The median age of our sample was 44 years and median gross annual household income was $50,000 - $74,999. The average household represented in the study owned or leased 1.6 motor vehicles at the time of the study. Four percent of our respondents indicated their primary vehicle was of hybrid electric-fuel technology, while three percent indicated it was an ethanol flex fuel vehicle. Once all vehicles within a household (not only primary) were included hybrid motor vehicles accounted for 2.4 percent of all vehicles represented in the survey, flexible vehicles accounted for 3 percent and diesel vehicles less than 1 percent.

When asked about whether respondents knew about the use of ethanol blends for use in fuels in the U.S., eighty-seven percent responded '*Yes*', 7 percent said '*No*' and the remaining 6 percent did not know an answer to the question. When asked whether participants have purchased ethanol blends in the past, 56 percent said they had, 40 percent indicated they have not and 4 percent did not know an answer.

It is worth mentioning the local regulations mandate the blend of ethanol under certain conditions. These conditions have been met during the last few years, so E10 replaced almost all gasoline sold in the state. with gasoline fuels meeting a E10 composition. Thus, in spite of stated responses indicating that no ethanol blend fuels were purchased in the past, all local residents almost certainly have used ethanol. Residents might not be aware of the ethanol included in their fuel because state labeling regulations do not require notification to the buyer that there is ethanol at least up to a 10 percent blend and minimum octane ratings were generally left unchanged even though included ethanol increased the lowest grade octane.

Table 1. Attitudes towards selected statements involving the use of different energy feedstocks to generate renewable fuels measured on a 1-5 Likert scale (1=Strongly Disagree, 3=Neither Agree nor Disagree, 5=Strongly Agree).

	*n**	*Mean*	*St. Dev.*
Fuel cells technology should play an important role as an alternative to traditional motor fuels†	86	4.17	1.19
Grasses such as switchgrass should play an important role in producing ethanol as an alternative to traditional motor fuels†	83	3.67	1.29
Sugarcane should play an important role in producing ethanol as an alternative to traditional motor fuels†	82	3.11	1.41
Corn should play an important role in producing ethanol as an alternative to traditional motor fuels	94	2.88	1.49
Wood from forests should play an important role in producing ethanol as an alternative to traditional motor fuels	87	2.43	1.45

*Excludes 'Do not know' responses.
†Statistically significant from '3=Neither agree nor disagree' at α=0.05.

Attitudes regarding the role that different technologies should play as alternative sources of energy for motor vehicles are summarized in Table 1. Note than in addition to biofuels, a fuel cell alternative was included as an option to compare biofuels to other technologies in terms of their perceived role as substitute to fossil fuels. Participants' attitudes showed that fuel cells reported the highest average value on a 5-point Likert scale (1=Strongly Disagree, 3=Neither Disagree nor Agree, 5=Strongly Agree) with a mean of 4.17. The use of grasses (e.g. switchgrass), sugarcane, corn and wood to produce ethanol for biofuels were rated in declining order. The ranking of corn and wood among cellulosic feedstocks perceived to have lesser potential as a renewable energy source compared to grass sources or cell fuels coincides with the findings of Aguilar (2009) regarding preferences for sustainable energy investments in the U.S.

Table 2 summarizes the attitudes toward selected statements regarding the use of ethanol as a blend fuel for motor vehicles. Ranked with the highest mean score was the following statement: "*The use of ethanol as a motor vehicle fuel benefits U.S. farmers*". It was followed by the statements indicating that "*The use of ethanol as a motor vehicle fuel helps reduce U.S. dependence on fossil fuels*" and "*The use of ethanol as a motor vehicle fuel has a positive impact on the environment*". All these three statements were statistically significant (α=0.05) from a neutral score of 3 (Neither agree nor disagree). The remaining statements listed in Table 2 were not statistically significant from a neutral position. It is worth noting that both statements aimed to capture attitudes regarding the impact of ethanol as a motor vehicle showed the highest number of "Do not know" responses.

Results of the conditional logit model are presented in Table 3. Results include estimated coefficients, standard errors, *z*-statistic, *p*-values and odd ratios. The latter were estimated by exponentiation of the coefficient estimate and interpreted as in Long and Freese (2006). Coefficients with negative signs indicate an inverse relationship between a unit increase in a continuous variable (e.g. price) or, in the case of a categorical variable, the inclusion of that characteristic (e.g. wood-derived ethanol), on consumer preference.

Table 2. Attitudes towards the use of ethanol as a fuel in motor vehicles using a 5-point Likert scale. (1=Strongly Disagree, 3= Neither Agree nor Disagree, 5=Strongly Agree).

	*n**	*Mean*	*St. Dev.*
The use of ethanol as a motor vehicle fuel benefits U.S. farmers†	92	3.78	1.23
The use of ethanol as a motor vehicle fuel helps reduce U.S. dependence on fossil fuels†	93	3.59	1.28
The use of ethanol as a motor vehicle fuel has a positive impact on the environment†	90	3.22	1.42
If available, and sold at the same price as comparable fuels, I prefer to buy ethanol blends over non-mixed fuels	95	3.07	1.47
If available, and sold at the same price as comparable fuels, I would prefer not to buy ethanol blend fuels	94	3.03	1.41
Regardless of price, I try to avoid buying ethanol blend fuels	96	2.84	1.38
Plant-derived fuels such as ethanol should be required by law to be used in motor vehicles	93	2.77	1.42
The use of ethanol as a motor vehicle fuel has a negative impact on the environment	87	2.68	1.34

*Excludes 'Do not know' responses.

†Statistically significant from '3=Neither agree nor disagree' at $\alpha=0.05$.

Results of the econometric analysis show that the most important fuel attribute behind consumer preference in our study was price. It has the largest estimated coefficient and the smallest *p*-value of all attributes. Odd ratio estimates suggest that a 1 dollar per gallon increase in the price of fuel will reduce the likelihood of the average consumer selecting that fuel by 93 percent. The inclusion of information regarding the use of ethanol derived from woody feedstocks had a strong and negative impact on consumers' preferences compared to a base level of not disclosing any information regarding the source of ethanol. The disclosure of information regarding the use of a motor vehicle blend source from woody feedstocks showed a reduction in consumer preference compared to the base level (no information) of 60 percent. The other fuel attribute coefficient with marginal statistical significance was that capturing the effect of E20 content. Results suggest that the average consumer would be less likely to select an E20 fuel over a E10 alternative by 39 percent *ceteris paribus*.

Table 3. Conditional logit results of choice-based task for motor vehicle fuels.

	Coef.	Std. Err.	z	P>z	e^b
Price	-2.725	0.509	-5.36	<0.001	0.066
High-octane (91)‡	-0.007	0.471	-0.01	0.989	0.993
Corn ethanol†	0.094	0.224	0.42	0.676	1.098
Wood-ethanol†	-0.901	0.288	-3.12	0.002	0.406
E20*	-0.493	0.286	-1.72	0.085	0.611
E85*	-0.566	0.445	-1.27	0.203	0.568
Opt-out alternative specific	0.016	0.297	0.06	0.956	1.017

n=810. Log-likelihood $Chi^2(5) = 49.25$; Prob > Chi^2 <0.001

‡Base level: Medium octane (89)

†Base level: No information of ethanol source disclosed

*Base level: E10

4. Conclusions and recommendations

These results are deemed preliminary and only reflect on the sample collected in Columbia, Missouri, and cannot be extrapolated to a larger population. Elicitation of consumer preferences suggests that among renewable feedstocks to produce biofuels grasses were ranked the highest, followed by cane crops, corn and woody materials at the bottom of the list.

There was some agreement among study participants that the use of ethanol as a motor vehicle fuel benefits U.S. farmers, helps reduce U.S. dependence on fossil fuels and has a positive impact on the environment. However, overall, respondents expressed a neutral attitude towards making plant-derived fuels such as ethanol a legal requirement to be used in motor vehicles.

Evaluation of choice-based stated preferences over an array of motor vehicle fuels capturing variables related to price, octane, ethanol content and origin results of a conditional logit model suggests that price was the main driver behind consumers' preferences. A 1 dollar per gallon increase in the price of fuel would cause a 93 percent reduction for that price over other fuels, holding remaining attributes constant across options. Disclosure of information regarding woody feedstock used to produce ethanol used in fuel blends had a negative effect on the general preference for fuels *ceteris paribus*. The opt-put alternative specific variable that captured the effects of a fuel with no ethanol and a low octane was not statistically significant. These preliminary findings suggests that although there is some indication of a potential barrier to the content of ethanol in fuel blends as denoted by the significance of the E20 coefficient, price will be the primary driver of consumption.

Future work will expand our study to a nationwide sample. Our present choice-based instrument asked participants to assume their vehicle in the choice-based model could take any level of ethanol blend. Forthcoming studies will be presented to estimate future demand, thus will include a question about stated preferences with regard to future vehicle purchases. Respondents will estimate consumption based on that motor vehicle. This approach was taken by Tomkins et al. (1998). Ideally, however, we will extend this approach further to include the sensitivity of the vehicle purchase to fuel prices.

A revised design of the fuel profiles will be generated. A new design will incorporate the combined effects of no ethanol and 87 octane fuels captured through a single alternative specific opt-out coefficient. This adjustment will allow us to distinguish between the effects of no ethanol and lower octane levels on general consumer preferences. Future work with focus groups will also evaluate the inclusion of information on the energy content per gallon of biofuel to capture lower energy levels present in ethanol blends as in Petrolia et al. (2010).

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