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Do Americans want ethanol? A comparative contingent-valuation study of willingness to pay for E-10 and E-85

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ABSTRACT

A nationwide contingent-valuation survey of consumer preferences for consumer fuel blends E-10 (a blend of 10% ethanol and 90% gasoline for use in standard vehicles) and E-85 (a blend of 85% ethanol and 15% gasoline for use in flex-fuel vehicles) was conducted to estimate willingness to pay (WTP) and identify key characteristics driving demand. Results indicate that overall perceptions of ethanol are positive, but ethanol is not the globally-preferred transportation-energy alternative, even among consumers with a positive WTP. Results indicate also that demand for E-85 is more price inelastic than E-10, with this result driven by consumers with no preference for E-10 but strong preferences for E-85. Finally, results also indicate that those consumers who are unsure about the micro-level benefits of E-85 are nonetheless more inclined to pay a premium.

1. Introduction

U.S. ethanol production has increased from less than two billion gallons in 2000 to nine billion gallons in 2008 (Renewable Fuels Association, 2009), due in part to high oil prices and increased government subsidies and blending mandates. This increased production and use has resulted in ethanol becoming the focus for a variety of hot-button issues like national security, climate change, shifts in agricultural production and conservation, and fuel, feed, and food prices. Interestingly, there is no consensus on whether ethanol represents a net positive or negative on most of these issues (see Daschle, 2007; Fargione et al., 2008; Hill et al., 2006; Runge and Senauer, 2007; Searchinger et al., 2008; Shapouri et al., 1995, 2002; Wang et al., 2007).

In spite of the surge in its production and its apparent centrality in discussions of the issues noted above, very little work has examined ethanol demand. Although an opinion poll was conducted by Harris Interactive on behalf of the Biotechnology Industry Organization (2006) and a report on consumer opinion was published on the Renewable Fuels Association website (2007), the authors are aware of no peer-reviewed study focused on this issue. In practice, ethanol is already blended with gasoline in many U.S. states, and although the Renewable Fuels Standard requires that a certain percentage of ethanol be blended with gasoline at a *national* level annually, a given gallon of gasoline may contain anywhere from 0 to 10% ethanol, and this percentage will typically vary from state to state and from one gas station to another.[1] Consumers typically cannot choose their preferred blend levels; they simply consume the particular blends sold at the various stations and, depending on the information provided at the pump, may or may not be aware of the ethanol content. Therefore, consumers are typically unable to express their preferences at the pump.[2]

[1] Blending is currently influenced by two somewhat contradictory requirements, both of which are codified in the Clean Air Act and both of which are administered by the Environmental Protection Agency. First, the Renewable Fuels Standard (RFS) establishes the minimum percentage of renewable fuels that must be blended nationally into conventional gasoline for sale to final consumers. In practice, the EPA implements the RFS by establishing a national blending requirement as a percentage of total expected use. Thus, based on a renewable fuels mandate of 11.1 billion gallons for 2009, the EPA has established a national blending requirement of 10.21%. Note that the RFS refers to the percentage of *aggregate* fuel production that must come from renewable sources. Second, the ethanol blend limit establishes the *maximum* percentage of ethanol that can be blended into a given gallon of conventional gasoline.

[2] One exception to this is that it has been observed that some stations advertise that their gasoline is "enriched with ethanol", whereas others advertise that their gasoline "is ethanol free". This evidence, though anecdotal, indicates clear differences in ethanol preferences.

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It is important to recognize that the facts that ethanol use is mandated by the government and that consumers have no choice at the pump are *irrelevant* to the question of what consumer preferences are. *Given the choice*, would consumers prefer ethanol blends over non-ethanol blends? This question has not been answered and it is this question that we sought to address here. Given the impossibility of ascertaining ethanol preferences from observed behavior, it is necessary to elicit preference information by alternative means. We did this via the contingent-valuation (CV) method. We developed and administered a nationwide CV survey to ascertain — *when given the choice between ethanol-blended fuels and non-ethanol blended fuels* — consumer preferences for E-10 (a blend of 10% ethanol and 90% gasoline for use in standard vehicles) and E-85 (a blend of 85% ethanol and 15% gasoline for use in flex-fuel vehicles) to estimate willingness to pay (WTP) and to identify key characteristics driving demand. Studies purporting to understand the benefits of ethanol have little grounds for making those claims without an understanding of underlying demand for the product. Our study will provide that critical piece of information to the ethanol debate.

Ethanol contains less energy per unit volume than gasoline and it cannot be used in most cars above the 10% blending level; therefore, for these two reasons, ethanol-based fuels are not perfect substitutes for conventional gasoline. The two forms in which ethanol is most commonly sold at the retail level is E-10, which can be used in most vehicles without engine modification, and E-85, which can be used only in flex-fuel vehicles or in vehicles whose engines have been modified. Thus, to speak of "ethanol" as a single product ignores important differences in the products, and therefore, potential differences in demand. Do consumers that prefer E-10 over conventional gasoline necessarily prefer E-85 over E-10? In other words, is the preference ordering consistent with ethanol share, or do some consumers prefer conventional gasoline over E-10 but E-85 over conventional gasoline? In short, is the difference between E-10 and E-85 one of degree or is it one of kind?

Furthermore, although ethanol may substitute for gasoline to some degree, it is not the only alternative. One may substitute other forms of energy or transportation, such as increased use of public transit or hybrid vehicles. Whereas one consumer may derive disutility from consumption of ethanol, another may simply have a preference ordering such that ethanol fuels rank below that of other, more-preferred substitutes. How does one's global preference ranking of ethanol impact demand? Additionally, demand may be influenced by peoples' notions of the impact of increased ethanol use on issues of national importance. Do Americans perceive ethanol as improving (or degrading) the environment? Do they perceive it as an economic stimulus? Do they perceive it as improving national security by reducing dependence on foreign oil? The association of such indirect benefits with the fuel, and the relative weight that individuals may attach to them, may therefore positively (or negatively) influence demand as well.

This study seeks to provide answers to the above questions in order to present a thorough analysis of demand for ethanol-based fuels, including estimates of what consumers are willing to pay to consume them, identification of key factors that influence demand, and a better understanding of how preferences for one ethanol fuel influences that of the other. This article is organized as follows. The next section describes survey design and data collected, followed by the general results of the survey; then, the econometric estimation methods are detailed, followed by the econometric results; the paper ends with some concluding remarks.

2. Survey design and data

In order to collect the required data for the study, we designed a 10-page, 49-question contingent-valuation (CV) mail survey. Surveys were mailed in April 2007, followed by a reminder letter two weeks later, then a second mailing of the survey two weeks after that. In an attempt to increase response rate, one-third of the sample received a $1 bill along with the survey; one-third received a promise of a $5 bill upon return of the survey; and one-third was given no incentive.[3] The sample consisted of a stratified (weighted by state population) random sample of 3000 persons from all 50 states and Washington, D.C. The sample was subdivided into 3 independent stratified samples of 1000 persons based on respondent incentive.

Table 1
Preference and perception questions included in survey.

#	Question	Response choices
1.	Assume the price of E-10 and conventional gasoline is the same. Would using E-10 instead of conventional gasoline to run your vehicle give you more overall satisfaction?	(1) Yes; (2) No; (3) Not sure
2.	Would using blends of fuel made up of more than 10% ethanol give you more overall satisfaction relative to what you would expect from using E-10?	(1) Yes; (2) No; (3) Not sure
3.	Which one of the following would you support as the best approach to reducing gasoline consumption in this country?	(1) Increase the use of public transportation; (2) Increase the use of vehicles which can run on gasoline with higher-ethanol blends; (3) Increase the use of electric vehicles, fuel-cell vehicles, or hybrid vehicles rather than increasing the use of ethanol.
4.	(Three questions) Compared to gasoline, the impact of increased usage of E-10 on the environment/economy/national security would be:	(1) Positive; (2) About the same; (3) Negative
5.	Please choose only one of the following reasons why you think the U.S. should pursue an alternative-fuels program:	(1) For national-security reasons alone; (2) For environmental reasons alone; (3) For economic reasons alone, even when we are not sure about the future price of oil; (4) I cannot see any reason why the U.S. should pursue an alternative-fuels program.

To ascertain whether demand differed across demographic groups, we collected data from each respondent on household size, number of vehicles owned or leased, age, gender, education level, annual income, state of residency, size of resident city, and political orientation. Additionally, demand may be influenced by consumers' preference ordering for conventional gasoline and different ethanol fuel blends, preference ordering among ethanol and other major transportation alternatives, preferences for alternative-fuel policies, and perceptions about ethanol's impact on the environment, the economy, or national security. Consequently, each respondent was asked the set of questions shown in Table 1 to collect the above preference/perception data.

For the E-10 WTP question, each respondent was asked whether he would be willing to pay $\$P_{E10}$ for E-10, or choose conventional gasoline at price $\$P_{GAS}$. The E-10 price was constructed according to energy equivalence, based on the U.S. Department of Energy's conversion yield of 1.52 times more mileage per gallon of conventional gasoline than 100% ethanol (United States Department of Energy, 2005). The price of conventional gasoline was held constant at $2.55 per gallon across all surveys (this was the prevailing national average price of regular gasoline when the survey was sent out in the spring of 2007); thus the energy equivalent price for E-10 was calculated as $2.55 [0.9 + (0.1/1.52)] = $2.46. Subsequently added to this amount was a randomly-assigned premium of 5, 10, 15, 20, or 25 ¢ per gallon to arrive at the stated E-10 price, P_{E10}. The WTP question for E-85 was worded and prices calculated in similar manner. The energy-equivalent price for E85

[3] See Petrolia and Bhattacharjee (in press) for more detail on the effects of incentive treatments.

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was $1.81. Although the premium varied across surveys, the premium each individual was asked to pay was the same for the two fuels (i.e., if the premium was 25¢ for E-10, it was also 25¢ for E-85).[4] Respondent understanding of energy equivalence and its relationship to price was critical; thus each respondent was given detailed information about energy equivalence and was asked questions to confirm understanding (see specific questions in Appendix). The E-10 WTP question was (with prices varied across surveys):

Suppose your car uses gasoline and you visit a gas station to buy gas. The gas station has both regular gasoline and E-10. The price of regular gasoline is $2.55/gallon and the price of E10 is $2.50/gallon. Which one would you buy?

(1) *I would buy E10 at $2.50/gallon, which means I choose to pay 5 cents a gallon more over the energy-equivalent price.*
(2) *I would buy regular gasoline at $2.55/gallon.*

In order to get an unbiased estimate of WTP, it is necessary to know whether an individual does not want to pay a particular premium because of the premium itself or simply because the individual does not want to buy the good at any price. Our survey, therefore, contained a follow-up question to individuals who refused to pay the premium (an approach similar to that of Hite et al., 2002). The follow-up question allows for identification of "protest" consumers. Thus, if the respondent chose (2) above, they were asked to respond to this follow-up question:

… [W]ould you purchase E10 at ***any*** *price lower than $2.50/gallon?*

(1) *Yes*
(2) *No.*

Although most vehicles require no modification to use E-10, most require some engine modification to use E-85 (unless the owner happens to own a flex-fuel vehicle, which was not the case for most respondents). We designed the survey such that changes in respondents WTP from E-10 to E-85 should be influenced by the change in ethanol concentration, not by engine compatibility issues. However, to account for the possible influence of the compatibility issue on WTP, we asked them the WTP question for E-85 first, then provided information about car engine compatibility and gave them estimated costs for engine modification. Those that responded positively to the WTP question were then asked to update their response, i.e., whether they would also incur the necessary expenditure (either to modify their existing engine or buy a flexible fuel vehicle) within a year in order to be able to consume E-85 (see specific questions in Appendix).

3. Survey results

The survey generated 748 returns (a 25% response rate). Table 2 contains the summary statistics of the data collected, as well as how each variable was specified in the econometric model. In comparison to U.S. census population statistics (United States Census Bureau, 2008), our sample was skewed slightly in favor of middle-aged, educated, upper-middle-class males. Median U.S. household income was $44,334, whereas the mean household income level of our sample was about $60,000. Forty-nine percent of the U.S. population was male, whereas 69% of our sample was male. The adjusted (accounting for 18 and older only) median U.S. age is 48, whereas the mean age of our sample was 58. Fifteen and one-half percent of the U.S. population held a bachelor's degree and 8.9% held a master's degree. Fifty-four percent of our sample had a high-school degree or less, 24% had completed a bachelor's degree, and 22% had a graduate degree. Differences between the sample and population statistics and how this issue was addressed are discussed in the subsequent econometric estimation section. Thirty-eight percent of respondents described themselves as politically conservative, 17% as liberal, 28% as neither conservative nor liberal, and 17% chose "I would rather not say".

Table 3 is a two-way table showing the individual and joint breakdown of responses to the two "satisfaction" questions. Forty-seven percent of respondents said they would derive more satisfaction from using E-10 relative to conventional gasoline, 31% said they were not sure if they would, and 22% said they would not. Forty percent of respondents indicated that they would also derive more satisfaction from using a blend with greater than 10% ethanol relative to E-10, but 43% said they were unsure, and 18% said they would not. Regarding the joint breakdown, most respondents fell along the diagonal; i.e., most respondents had the same response to the two questions. This result implies that demand for E-10 may be a reasonable proxy for demand for a blend with greater than 10% ethanol. However, 12% of respondents indicated that although they

Table 2
Variable summary statistics and descriptions.

Variable	Variable type and description	Freq.	Mean	Std. dev
AGE	Ordered categorical: 18–39 = 1, 40–59 = 2, 60–79 = 3, 80+ = 4	573	2.44	0.84
EDUCATION	Ordered categorical: some school–no H.S. diploma = 1, high-school diploma = 2, some college–no degree = 3, college degree = 4, advanced degree = 5	662	3.38	1.16
FEMALE	Binary: female = 1	664	0.31	0.46
INCOME	Ordered categorical: <$40 K = 1, $40 K–80 K = 2, >$80 K = 3, did not say = 0	523	3.80	1.66
MIDCLASS	Binary: $40 K–80 K = 1, = 0 otherwise (used in selection model only in lieu of INCOME)	523	0.39	0.49
Party	3 binary dummy variables for each response (CONSERVATIVE, LIBERAL, MODERATE); MODERATE is base dummy	632	See Table 4	
Satisfaction	5 binary dummy variables based on responses to satisfaction questions (E-10/>E-10 response: NONO, NSNS, YESYES, NOYES, YESNO; NS–NS is base dummy	656	See Table 3	
Policy	3 binary dummy variables for each response (PUBLIC, ETHANOL, HYBRID); ETHANOL is base dummy	614	See Table 4	

Table 3
Two-way table of responses to satisfaction questions ($N = 656$).

		Would using blends of fuel made up of more than 10% ethanol give you more overall satisfaction relative to what you would expect from using E-10?			
		No	Not sure	Yes	Total
Assuming equal price, would using E-10 instead of conventional gasoline to run your vehicle give you more overall satisfaction?	No	14%	5%	4%	22%
	Not sure	1%	26%	4%	31%
	Yes	2%	12%	32%	47%
	Total	18%	43%	40%	100%

[4] It should be noted that the premium is in nominal terms, not energy equivalence; i.e., once the energy-equivalent price is established, the premium added to it is identical between E-10 and E-85. Thus, paying a 5-cent premium on E-85 represents a (very slight but real) higher premium per unit of energy relative to that of E-10. Microeconomic theory predicts, then, that, all else equal, the probability of WTP a premium for E-10 should be higher, or at least no lower, than that of E-85. This implies that the premium is biased in favor of E-10. However, the results do not bear this bias out. In fact, as the results reported in this article show, the exact opposite was true: respondents were more likely to pay a premium for E-85 than for E-10.

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derived additional satisfaction when switching from gasoline to E-10, they were unsure of whether they would derive additional satisfaction when switching to a higher-ethanol blend.

Table 4 is a two-way table showing the individual and joint-response rates for the reason-why-government-should-pursue-alternative-fuels question versus the best-approach-to-reducing-gasoline-consumption question and versus political orientation, respectively. Fifty-one percent of respondents indicated an increase in hybrid, fuel-cell, and other non-petroleum-based vehicles, 25% said increased ethanol use, and 24% said increased public transit options. It should be noted that this pattern held even among those that answered "Yes–Yes" to the satisfaction questions, with 104 out of 199 of such respondents (51%) preferring non-ethanol alternative vehicles, and 41 (24%) preferring increased public transportation, leaving only 54 (25%) to chose increased ethanol use as their preferred policy. Thus, even those who are expected to derive the most satisfaction from ethanol (and as the econometric results show, more likely to pay a premium), do not, in fact, hold ethanol as their globally-preferred alternative transportation-fuel solution. Forty percent of respondents indicated that the federal government should pursue an alternative-fuels program for environmental reasons, 38% said for national-security reasons, and 18% said for economic reasons. Finally, although the percentage differences are small, those who support increased ethanol use tend to support alternative fuels for national-security reasons, whereas those that support hybrid cars, etc., tend to support alternative fuels for environmental reasons.

The results to the alternative-fuels program question are more interesting, however, if broken down according to political orientation. Self-described political "liberals" overwhelmingly choose the environment as the main reason to pursue alternative fuels, whereas conservatives choose national security. Moderates choose the environment slightly over national security, whereas those that choose to conceal their political identity did the opposite.

Most respondents, do, however, perceive increased ethanol use to have some positive impact on the country (Table 5). Sixty-eight percent, 60%, and 54% of the respondents indicated that increased ethanol use would have a positive impact on the nation's environment, economy, and national security, respectively, whereas only 8%, 12%, and 1% said the impact would be negative.

Out of the 748 respondents, 594 individuals (79%) responded to both WTP questions. The majority of non-respondents to the WTP questions did not reply to other survey questions either. (We discuss the issue of missing observations in more detail in a later section of the article.) Of those that responded, 134 respondents (23%) stated that they were willing to a pay some premium for both E-10 and E-85, 151 individuals (25%) were ready to pay a premium for E85 but not E10, 15 individuals (3%) were willing to pay a premium for E10 but not E85, and 294 (49%) said they would not pay any premium for either of the fuels. Table 6 contains the frequency of WTP responses at each bid level for E-10 and E-85, as well as frequency of responses to the selection questions ("any price < bid"). As expected, probability of WTP decreases with bid, with one exception at the highest bid level for E-85. This anomaly is discussed further subsequently. Table 7 shows the percentage breakdown of "Yes" WTP responses for E10 and E85 across the nine response combinations to the "satisfaction questions". For example, the "4%" figure in the northwest corner of the table indicates that 4% of those who answered "No–No" to the satisfaction questions were willing to pay a premium for E-10. Similarly, 14% of respondents from that same group were willing to pay a premium for E-85.

Table 5
Percentage breakdown of perceived impact of more usage of E-10 relative to conventional gasoline.

Relative to conventional gasoline the impact of more usage of E-10 on …				
	$N =$	Worse	About the same	Better
The economy would be…	638	8%	24%	68%
The environment…	633	12%	28%	60%
National security…	623	1%	45%	54%

As mentioned earlier, although premia vary across individuals, the amount of the premium each individual has been asked to pay for each of the two fuels is the same, and WTP questions were based upon a choice between E-10 versus regular gasoline and E-85 versus regular gasoline. The results in Table 7 indicate that respondents are more willing to pay a premium for E-85 than for E-10, regardless of stated preferences. This phenomenon held even among those that indicated that they would derive no additional satisfaction from consuming either of the ethanol blends over conventional gasoline. However, only 7 respondents indicated a WTP for E-10 in spite of deriving no additional satisfaction from E-10, and only 18 respondents indicated a WTP for E-85 in spite of deriving no additional satisfaction from E-85. We consider these frequencies to be too small to be indicative of any systematic pattern.

These apparently inconsistent responses notwithstanding, it is reasonable to assume that the results shown in Table 7 are simply reflecting stronger preferences for E-85 relative to E-10. It is possible, however, that these results are indicative of some systematic effect caused by the bids. The law of demand holds that WTP should decline with price. To test if results were consistent with microeconomic theory, we constructed a Kruskal–Wallis equality-of-populations rank test to test the null hypothesis that bid level had no effect on the likelihood of a Yes response to WTP for E-10 and E-85, respectively. The null hypothesis was rejected at the 1% significance level for both E-10 and E-85, indicating that probability of WTP is, in fact, inversely related to price for both fuels. However, the results were stronger for E-10, indicating that WTP for E-10 was influenced more by price than was WTP for E-85. In other words, results of the test indicate that demand for E-85 is more price inelastic.

The above results, however, do not aid in better understanding the higher frequency of Yes responses to WTP for E-85 shown in Table 7. To address this, we separated respondents into 4 groups based on

Table 4
Individual and joint percentage breakdown of primary reason for pursuing an alternative-fuels program by preferred alternative policy ($N = 567$) and by political orientation ($N = 598$).

		Why should the federal government pursue alternative-fuels program?				
		Economic	Environmental	National security	No reason	Total
Best approach to reducing gasoline consumption	Increased public transport	3%	10%	9%	2%	24%
	More ethanol	6%	7%	11%	0%	25%
	Hybrids, fuel-cell cars, etc.	10%	22%	17%	2%	51%
	Total	18%	40%	38%	4%	100%
Political orientation	Conservative	9%	10%	17%	2%	38%
	Liberal	2%	12%	3%	0%	17%
	Neither	4%	13%	11%	1%	29%
	Did not reveal	3%	5%	7%	1%	16%
	Total	18%	40%	38%	4%	100%

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Table 6
WTP response by bid and follow-up response (willingness to pay for E-10/E-85 at any price < bid).

Premium	E-10			E-85		
	N	Yes	Pr(Yes)	*N*	Yes	Pr(Yes)
5¢	117	51	0.44	109	66	0.61
10¢	123	39	0.32	117	64	0.55
15¢	146	36	0.25	138	62	0.45
20¢	116	15	0.13	104	37	0.36
25¢	148	17	0.11	136	61	0.45
Total	650	158	0.24	604	290	0.48
Adjusted for E-85 compatibility issue:					46	0.08
Any price < Bid	433	262	0.61	283	137	0.48
Adjusted for E-85 compatibility issue:					3	0.01

WTP responses for E-10 and E-85: Yes to both WTP questions, No to both, No to E-10 but Yes to E-85, and Yes to E-10 but No to E-85. We then constructed a Kruskal–Wallis statistic to test, for each group, the null hypothesis that bid level had no effect on the likelihood of a Yes response (the last group was not tested, however, because it contained only 15 respondents). The null hypothesis was rejected at the 1% level for the Yes–Yes and No–No WTP groups. In other words, of those respondents that consistently answered Yes or No to WTP for both fuels, bid was significant; thus, these groups appear to follow the law of demand. For those that answered No to E-10 but Yes to E-85, however, i.e., for those driving the differences in percentages between E-10 and E-85 in Table 7, the null hypothesis could not be rejected. This result implies that for this sub-set of respondents, the higher frequency of Yes responses to WTP for E-85 relative to E-10 is not an artifact of the bids, and that there exist consumers who have no preference for E-10 but have strong preferences for E-85 which do not appear to be tempered by higher premia. This issue is addressed further in subsequent sections.

4. Econometric estimation methods

We estimated a probit model with sample selection (van de Ven and van Praag, 1981) to estimate mean WTP for E-10 and E-85. Choosing to pay a premium for an ethanol-blended fuel is contingent on whether an individual wants to buy the fuel in the first place. Given the controversial issues surrounding ethanol production and usage, it is likely that some individuals do not want to buy any ethanol-based fuel, regardless of the price being offered. Thus, individuals who stated that they did not want to buy E-10 (or E-85) *at any price* (i.e., that responded "No" to the follow-up question stated above) were classified as "protest" consumers. The probit model with selection has the following structure; $Y_{1i}^{*}=X_{1i}\beta_1+\varepsilon_{1i}$, $Y_{2i}^{*}=X_{2i}\beta_2+\varepsilon_{2i}$, where Y_{2i}^{*} is the utility function of an individual reflecting one's overall attitude towards an ethanol-blended fuel (signified by a "No" response to buying E-10 (or E-85) *at any price*), and Y_{1i}^{*} is the utility difference between buying the fuel at $\$P_E$ and buying conventional gasoline at \$2.55. X_{1i} and X_{2i} are the respective vectors of covariates for individual (i), β's are the associated coefficient parameters and ε_i's are respective error terms. X_1 and X_2 share at least one unique element. Y_{ji}^{*} and Y_{ji} are associated in the following manner: for every individual (i), $Y_{ji}=\left\{\begin{array}{ll}1 & \text{if } Y_{ji}^{*}>0\\ 0 & \text{if } Y_{ji}^{*}\le 0\end{array}\right\}$ for $j=1,2$; however, Y_{1i} is observed only if $Y_{2i}=1$.[5] Thus, whereas the second probit equation is based on the complete sample, the first probit equation is based on a selected (or censored) sample. It is necessary to know whether an individual does not want to pay a particular premium because of the premium itself or simply because the individual does not want to buy the fuel at any price. Use of the selection model thus helps to dissociate these two types of consumers and rectify selection bias. If correlation between ε_{1i} and ε_{2i} is zero, estimating the selection equation separately would not result in any loss of efficiency. However, if correlation is present, not only is joint estimation efficient, but selection bias is removed as well.

Model specification was as follows. The selection model contained the variables AGE, EDUCATION, FEMALE, MIDCLASS, HYBRID, and PUBLIC (see Table 2 for variable specification). The MIDCLASS variable was used in lieu of INCOME based on the hypothesis that preferences among the middle-class may differ from those of both the "poor" and "rich". For the selection model, income, per se, should not be relevant because the question is posed to determine whether they are open to the good in question at all, regardless of price. It should be when the question is posed at particular prices that income should become a relevant factor via the budget constraint. Consequently, we use MIDCLASS in the selection model and INCOME in the WTP model. The alternative policy variables (HYBRID and PUBLIC) were included in the selection model because we assumed that one's decision to buy an ethanol-blended fuel at all depends upon one's preferences for alternatives to ethanol.

The WTP model contained the variables LNBID, AGE, EDUCATION, FEMALE, INCOME, CONSERVATIVE, LIBERAL, NONO, YESYES, NOYES, and YESNO. We included the satisfaction-question variables in the WTP model rather than in the selection model based on the assumption that one will choose to pay a premium only if one derives additional utility from the good in question. Originally, the models were specified using the satisfaction variables separately in order to capture the effect of preferences for one fuel on WTP for the other. Under this specification, however, the "NO" variables were not statistically significant; e.g., WTP for E-85 could not be explained by a non-preference for E-10, and vice-versa. As Table 3 shows, most respondents were consistent in their responses to the satisfaction questions; i.e., those that responded No, Not Sure, or Yes to one also responded No, Not Sure, or Yes, respectively, to the other. For such consumers, these results indicate that E-10 and E-85 differ in degree only. However, some respondents gave divergent responses, and as discussed earlier, there appears to be a substantial sub-set of consumers who have no preference for E-10 but strong preferences for E-85. For these consumers, E-10 and E-85 differ in kind. Based on these interpretations, we constructed joint-response variables for each combination of responses to the satisfaction questions because these specifications should better reflect the complexity of preference

Table 7
Percentage of respondents in each category that responded positively to WTP for E-10 and E-85.

		Would using blends of fuel made up of more than 10% ethanol give you more overall satisfaction relative to what you would expect from using E-10?					
		E-10			E-85		
		No	Not sure	Yes	No	Not sure	Yes
Assuming equal price, would using E-10 instead of conventional gasoline to run your vehicle give you more overall satisfaction?	No	4%	3%	8%	14%	46%	45%
	Not sure	14%	17%	11%	14%	40%	54%
	Yes	31%	31%	43%	31%	60%	67%

[5] Actually, in this survey, the selection question was asked *after* the WTP question because, in this context, it made sense to order the questions this way. Thus *every* respondent was asked to respond to the WTP question, but not all respondents actually answered the selection question. However, the response to the selection question for those stating a positive WTP (and thus not asked to respond to the follow-up question) could be inferred. Similarly, for those that responded "No" to the selection (follow-up) question, their response to the WTP question was suppressed.

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interactions. The NONO and YESYES variables are self-explanatory. The NOYES variable represents all respondents who expressed a positive change in satisfaction from E-10 to a fuel with greater than 10% ethanol, Specifically, these respondents stated either "no" to Question 1 in Table 1 then "not sure" or "yes" to Question 2, or stated "not sure" then "yes". Conversely, the YESNO variable represents the opposite case: respondents replied either "yes" to Question 1 then "not sure" or "no" to Question 2, or "not sure" then "no".

Because of close correlation between political orientation and preferred policy alternatives, the political orientation (Party) variables (CONSERVATIVE and LIBERAL) were used in the WTP model only. Finally, although response rate was significantly higher for those respondents receiving the $1 cash incentive, incentive type was found to have no significant impact on WTP estimates, and thus no incentive variable was included in the econometric estimation.

We fit the following joint maximum-likelihood function (van de Ven and van Praag, 1981) to estimate the model for both fuels, E-10 and E-85:

$$\prod_{i=1}^{N1} \Phi_2(\beta_1' X_{1i}, \beta_2' X_{2i}; \rho) \cdot \prod_{i=N1+1}^{N2} \Phi_2(-\beta_1' X_{1i}, \beta_2' X_{2i}; \rho) \cdot \prod_{i=N2+1}^{N3} \Phi(-\beta_2' X_{2i}),$$

where observations 1,..., $N1$ are respondents willing to pay the stated premium (i.e. for them, $Y_1 = 1$ and $Y_2 = 1$), observations $N1+1$,..., $N2$ are respondents not willing to pay the stated premium but willing to pay some lower price (i.e. for them, $Y_1 = 0$ and $Y_2 = 1$), and observations $N2+1$,..., $N3$ are "protest" respondents, i.e., those not willing to pay any price (i.e., for them $Y_2 = 0$), $\Phi_2(\cdot)$ is CDF of a bivariate normal, Φ is CDF of univariate normal distribution and ρ is correlation between ε_{1i} and ε_{2i}. Estimation was carried out using the HECKPROB module in Stata version 10 (Stata Corporation, 2007). To correct for potential biases in WTP estimates due to differences between the sample and the population, a weight variable was constructed as the ratio of population frequency over sample frequency using income and gender data. The estimation was then weighted using this weight variable (see, for example, Lusk et al., 2003). Furthermore, because the responses for the two fuels were taken from the same survey, we assumed cross-equation correlation across the error terms of the two models. Thus, we also employed a post-estimation procedure in Stata (SUEST) to obtain adjusted standard errors. Mean and median WTP for E-10 and E-85 were calculated using the method for a log-linear WTP function as described in Haab and McConnell (2002). To provide some additional information on the distribution of WTP, we also calculated the Turnbull distribution-free means and upper and lower bounds on WTP (Haab and McConnell, 2002).

5. Estimation results

Table 8 contains the estimated coefficients and standard errors for both the selection and WTP equations for E-10 and E-85. For the E-10 selection equation, all variables were statistically significant at least at the 10% significance level except for FEMALE and MIDCLASS. Results indicate that the probability of buying E-10 is lower for older respondents. Additionally, as expected, those that prefer increased public transit options (PUBLIC) and non-ethanol-fueled vehicle alternatives (HYBRID) are less-likely to buy E-10. The education variable was significant and positive, indicating that acceptance of E-10 increases with education level.

Now, assuming that one would buy E-10 at some price, we turn to the WTP equation. Here, the significant demographic variables were education and a liberal political orientation. However, in this case, the sign on education is negative. Thus, the results imply that more-educated people are more likely to accept E-10 at *some* price, but that they are less-likely to pay a *premium* for it. Politically "liberal" respondents, on the other hand, are more likely to pay a premium for E-10. Three of the satisfaction variables were also significant. As expected, the NONO respondents, i.e., those that said "No–No" to the questions of whether E-10 would give them more satisfaction than conventional gasoline and whether a blend with greater-than-10% ethanol would give them more satisfaction than E-10 are less-likely to pay a premium for E-10, whereas the YESYES respondents are more likely. Additionally, the YESNO respondents are more likely to pay a premium. The NOYES variable was not significant.

Table 8
Coefficient estimates and standard errors for E-10 and E-85 probit models with selection; coefficients in bold were significant at the 5% level.

	E-10			E-85		
	Coef.	Robust s.e.	$P>z$	Coef.	Robust s.e.	$P>z$
WTP						
CONSTANT	**14.76**	**3.67**	**0.00**	**5.24**	**1.22**	**0.00**
LNBID	**−15.72**	**3.78**	**0.00**	**−7.66**	**1.73**	**0.00**
AGE	0.14	0.12	0.26	−0.01	0.15	0.97
EDUCATION	**−0.24**	**0.08**	**0.00**	0.00	0.11	0.99
FEMALE	0.08	0.18	0.67	0.07	0.18	0.72
INCOME	0.06	0.06	0.28	−0.05	0.06	0.40
CONSERVATIVE	−0.05	0.16	0.76	0.03	0.22	0.89
LIBERAL	**0.80**	**0.21**	**0.00**	**0.28**	**0.14**	**0.04**
YESYES	**0.80**	**0.23**	**0.00**	0.27	0.19	0.17
NONO	**−1.22**	**0.44**	**0.01**	**−0.71**	**0.27**	**0.01**
YESNO	**0.55**	**0.21**	**0.01**	−0.10	0.38	0.80
NOYES	−0.42	0.45	0.34	−0.19	0.23	0.42
Selection						
CONSTANT	**0.88**	**0.43**	**0.04**	0.61	0.49	0.21
AGE	**−0.21**	**0.11**	**0.05**	−0.09	0.12	0.46
EDUCATION	**0.23**	**0.08**	**0.00**	0.13	0.09	0.13
FEMALE	0.23	0.18	0.20	0.09	0.18	0.61
MIDCLASS	−0.25	0.16	0.11	−0.10	0.21	0.63
HYBRID	**−0.54**	**0.20**	**0.01**	−0.16	0.17	0.36
PUBLIC	**−0.73**	**0.24**	**0.00**	−0.44	0.31	0.16
rho	−0.92	0.14		0.99	0.05	
Log-likelihood	−348.9			−358.6		

The model for E-85 did not perform as well, both in explaining the variation in preferences for E-85 at any price (selection) or in WTP. No variables in the selection equation were significant. For the WTP equation, the only significant variables (other than LNBID and CONSTANT) were NO–NO and LIBERAL. As expected, the former was negative and the latter, positive.

Table 9 contains the estimated WTP values for E-10 and E-85 based on both the econometric results and using the Turnbull lower-bound method. Mean WTP premium for E-10 was estimated to be $0.12 per gallon based on parametric results, with a $0.06 per gallon (with a +/− $0.01 upper and lower bound) Turnbull lower-bound estimate. Mean WTP premium for E-85 was estimated to be $0.15 per gallon based on parametric results, with a $0.13 per gallon (with a +/− $0.01 upper and lower bounds) Turnbull lower-bound estimate. Thus, on average, respondents appear ready to pay between six and twelve cents per gallon over the energy-equivalent price of conventional gasoline for E-10, and 12–15 cents per gallon premium for E-85.

Table 9
Estimated WTP premium ($/ gallon) for E-10 and E-85.

	E-10	E-85
Log-linear model		
Mean	$0.124	$0.152
Median	$0.119	$0.135
Turnbull		
Mean	$0.062	$0.131
Lower bound	$0.054	$0.120
Upper bound	$0.070	$0.142

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It should be noted that, as mentioned previously, we informed those respondents willing to pay a premium for E-85 that it would be necessary for them either to have their existing vehicle engine modified (for about $1000) or buy a new flex-fuel vehicle, and asked them whether they would be willing to incur this additional cost within a year in order to be able to consume E-85. Out of the 290 individuals who were ready to pay a premium for E-85, only 48 responded that they would incur the additional cost with a year, and of the 283 that indicated that they would be willing to pay *some* price for E-85, only 3 said they would incur the added cost within a year. Therefore, the estimated WTP value for E-85 reported above should be taken with a grain of salt; it represents what consumers would pay *if they were actually able to consume it*. Another interpretation is that the estimated WTP applies, but not in the short-term; given enough time, however, consumers will be able to adjust their vehicle-fuel compatibility and actually be able to consume the good in which they have today expressed interest.

6. Conclusions

First, we wish to repeat that our survey had a response rate of 25%; thus 3 out of 4 would-be respondents did not contribute their opinions, and thus our results may not necessarily be representative of the general public. However, in as much as our sample represents the general population, the following can be said.

The results of our survey indicate that the overall perception of ethanol is positive. The majority of respondents perceived ethanol to have a positive influence on the environment, the economy, and on national security. Additionally, results indicate that there exists a positive WTP a premium for both E-10 and E-85, with apparently stronger preferences (i.e., greater WTP) for E-85. Additionally, results indicate that demand for E-85 is more price inelastic relative to E-10, with this result being driven by some consumers with no preference at all for E-10 but strong preferences for E-85 that appear to be non-responsive to price increases. Results also indicate that those consumers who are unsure about the micro-level benefits of E-85 are nonetheless more inclined to pay a premium, i.e., to err on the side of more ethanol.

These results, however, must be kept in perspective. In spite of these positive results, it is also apparent that ethanol is not the globally-preferred transportation-energy alternative: most consumers indicated a preference for increased public transit or non-ethanol-based energy sources over ethanol, even among those with a positive WTP for ethanol blends. These results, then, indicate that the push by industry and government to promote ethanol use may run counter to public demand: although consumers have some preferences for ethanol blends, they would nonetheless prefer something else even more.

Finally, the results of the econometric modeling indicate that acceptance and WTP for E-10 can be explained by demographic and other preference variables, but acceptance and WTP for E-85 can not (at least with the variables used here). Thus, although preferences for E-85 appear to be universally stronger than those of E-10, the reason why is not yet apparent. It is left to future research to identify the key drivers of demand for E-85.

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Appendix A. Survey questions pertaining to energy equivalence and engine compatibility of E-10 and E-85

Please read the following paragraphs carefully before answering the questions of this section.

- *E10 contains 10% ethanol, and because ethanol has less energy than gasoline, your vehicle would need more E10 to drive the same distance than it would if it used regular gasoline, irrespective of the vehicle you use.*
- *Fuel-cost = (price of the fuel) * (amount of fuel used). Because the amount of E10 you need to drive the same distance is greater compared to regular gasoline, E10 has to be priced less than regular gasoline so that total fuel cost remains the same. The price at which the cost of E10 usage matches with the cost of gasoline usage is known as the "energy equivalent" price.*
- *Specifically, if the price of regular gasoline is $2.55/gallon, then the energy equivalent price of E10 would need to be $2.45/gallon. This implies that when the price of regular gasoline is $2.55/gallon, and you choose to pay anything higher than $2.45/gallon to use E10 instead, you effectively choose to pay more per gallon to drive your vehicle.*

A1. Are you clear *about the fact that* **because E-10 contains ethanol**, *you have to buy more E-10 compared to regular gasoline to drive the same distance?*

1 — Yes *2 – No*

Please read the following paragraph carefully before answering the questions in this section.

Similar to E-10, E-85 is an alternative to regular gasoline. It contains a higher % of ethanol (85%) and lower % of gasoline (15%), and is already available in some parts of the country. As noted earlier, there is less energy in ethanol than there is in gasoline. Consequently, if the regular gasoline price is $2.55/gallon, the "energy-equivalent" price of E-85 is $1.81.

A2. *We just want to reiterate that you consume 75* **fewer** *gallons of gasoline* **and** *75* **more** *gallons of ethanol if you use 100 gallons of E-85 instead of 100 gallons of E-10.* **Is it clear** *to you that ethanol consumption significantly increases and gasoline consumption significantly decreases when you substitute E-85 for E-10?*

1 — *Yes, the increase in ethanol usage from E-10 to E-85 is clear to me*
2 — *No, the increase in ethanol usage from E-10 to E-85 is not clear to me*

A3 ♣ *You have just stated that you would like to use E-85. However, unless you currently own a flexible fuel vehicle or have modified your existing car engine, you cannot use E-85, when*

➢ *modifying your existing engine costs about $1000, and*
➢ *a flexible fuel vehicle is the same as a regular vehicle except it can run on a blend of fuel that contains up to 85% ethanol.*

Assuming that the price difference between gasoline and E-85 remains the same as mentioned above over the next 5 years, **which one of the following actions are you most likely to take***?*

1 — *I will modify my car engine within a year in order to use E-85*
2 — *Assuming that the price of a flexible fuel vehicle would be the same as any other new car in the same class, I will buy a Flexible Fuel Vehicle within a year in order to use E-85*
3 — *I do not intend to modify my existing vehicle's engine or buy a new car within the coming year. However, if I buy a new car in the future, it will be a Flexible Fuel Vehicle that can use E-85*

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4 — *I will neither modify my car's engine nor buy a Flexible Fuel Vehicle now or in the foreseeable future, which means even if I want to use E-85, I will not be able to do so*

5 — *I am currently using E-85 to run my vehicle and will keep using E-85*

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