Estimating Willingness to Pay for E10 fuel: a contingent valuation method

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Estimating Willingness to Pay for E10 fuel: a contingent valuation study

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Abstract

In this study, we measure willingness to pay for E10 fuel by US consumers employing a contingent valuation technique in a simultaneous latent variable equation framework. The simultaneous equation framework helps us to understand the way consumers' perceptions about ethanol are developed and influence their respective buying behavior. We fit various models and compare model efficacies and differences in WTP measure. Each model varies in the way we measure consumers' perception towards ethanol and in the way information is integrated into the random utility framework. Interaction between intended purchases of E10, perceived environmental, economic, and national security benefits are examined. We found self-described liberals have significantly higher WTP; WTP is higher for males; and WTP increases as familiarity with ethanol increases. Supporters of alternative fuels, but who are not sympathetic to ethanol, have significantly lower WTP for E10.

JEL Classification: **C12**, **C35**, **D12**

Keywords: E10 ethanol, perceptions and economic choice, latent variable, random utility models

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1. Introduction

Recent work by Kotchen and Moore (2007) and Kahn (2007) highlights the link between macro-level environmental preferences and micro-level consumption choices. This link is especially important for goods such as green electricity (Kotchen and Moore) and particular modes of transportation (Kahn) because the direct benefits that these goods deliver at the micro-level are not necessarily the distinguishing attributes of the goods; rather it is the indirect benefits (real or perceived) accruing at the macro-level that define the good. Thus, green electricity delivers direct benefits at the household level that are indistinguishable from those of brown electricity; the difference lies in the indirect, upstream benefits, where it is believed that green electricity production is environmentally superior, and thus perceived to deliver environmental benefits.

The twist is that these indirect benefits – the benefits that define the good – are likely those about which the consumer is least certain; i.e., they may be measured with error. This error derives from the fact that these benefits may be measured (perceived) according to some heuristic rather than through a detailed rationalization process, and this is dependent on how the individual perceives the relationship between their micro-level consumption choices and the macro-level outcome.

To build upon previous work into the relationship between macro-level preferences and micro-level consumption choices, we undertook a nationwide contingent-valuation survey on WTP for E-10, a fuel blend of 10 percent ethanol and 90 percent gasoline that can be used in most vehicles, and incorporated factor analysis into the random utility framework to estimate WTP. Additionally, this paper attempts to uncover not only how environmental preferences and perceptions influence consumption choices, but also how economic and national-security preferences and perceptions influence them as well.

The survey was designed to elicit perception data at three cognitive levels: 1) *overall* satisfaction; 2) environmental, political, and economic perceptions in *general*; and 3) perceptions on *specific* issues such as impacts on greenhouse gasses, rural-sector jobs, and government expenditures on national security. To analyze these data, we introduce an application of simultaneous latent variable modeling and compare these results to those from the more-commonly-used single-equation probit-type models.

In addition to the types of questions used to collect perception data at various cognitive levels, it is critical how the answers to these questions are used and what modeling framework is chosen. Of particular concern is how we capture heterogeneity in perception variables, and integrate these into WTP estimation. Whitehead (2006) and Danielson et al. (1995) found that perception variables are determined by respondent demographics, environmental knowledge, and environmental attitudes. Based on these findings, one should expect less-reliable WTP estimates if heterogeneity is ignored. To address this issue and to extend the earlier findings of Whitehead et al. (2006), we allow multiple perception indicators to vary across individuals and to be used simultaneously in the WTP equation. Finally, perception variables are likely influenced by the same unobserved characteristics that influence willingness to pay, resulting in endogeneity bias. If unobserved preferences are correlated with perceptions and willingness to pay, the coefficient on the perception variable will be biased (Whitehead, 2006).

This article is organized as follows. The next section describes the models of stated willingness to buy E10 capturing the relationship between WTP, consumers' subjective perceptions about benefits and the employed estimation method. Section 3 summarizes the basic features of the CV survey instrument and data used in the analysis. Section 4 presents the results. Section 5 summary and conclusions.

2. Modeling Consumer Perceptions and WTP

The general model presented here is a modified version of the standard Random Utility Model (RUM) framework (see, for example, Haab & Mcconnell 2002), and takes the form of a simultaneous latent variable model (SLVM) with two basic components: a structural component and a measurement component. The structural component estimates how the latent variables are interrelated among themselves and influence choice of regular gasoline versus E10, and the measurement component identifies and measures the latent variables.

Let an individual's utility associated with E10 and its regular alternative (gasoline) be characterized as

$$U_{E10} = \gamma_{E10}\mathbf{X_u} + \beta\eta_{b,E10} + \theta_{E10}(M - P_{E10}) + \xi_{E10} \qquad (2)$$

$$U_{GAS} = \gamma_{GAS}\mathbf{X_u} + \theta_{GAS}(M - P_{GAS}) + \xi_{GAS} \qquad (3)$$

where **X** is a (KX1) vector of explanatory variables representing personal (demographic and psychological) characteristics of individual consumers and γ_j is the (1XK) dimensional vectors of associated parameters. $\eta_{b,E10}$ is a continuous latent variable, representing perceived benefit associated with purchase of E10, and β is the associated parameter. $\eta_{b,GS}$ is standardized to zero, and does not appear in (3). M is individual's income and θ_j is the parameter associated with income. P_{E10} and P_{GAS} are the prices observed by the respondent for each fuel, respectively. ξ_{E10} and ξ_{GAS} are normally-distributed disturbances.

Let $\eta_u = U_{E10} - U_{GAS}$ be the indirect utility differential between E10 and regular (unleaded) gasoline. We assume that marginal utility of income remains the same over the two alternative situations, so $\theta_{E10} = \theta_{GAS} = \theta$. Based on equation 2 and 3 the utility differential is

$$\eta_u = \gamma_u X_u + \beta\eta_b + \theta p + \zeta_u , \qquad (4)$$

where $\gamma_u = (\gamma_{E10} - \gamma_{GAS})$, $p = P_{E10} - P_{GAS}$ (i.e., the premium on E10) and $\zeta_u = \xi_{E10} - \xi_{GAS}$.

The generic structure for the latent perception variable is the following;

$$\eta_b = \boldsymbol{\gamma}_b \mathbf{X}_b + \zeta_b \qquad (5)$$

where $\boldsymbol{\gamma}_b$ is the vector of the associated parameters respectively, and ζ's are normally-distributed errors. Combining equation 4 with 5 in matrix notation yields the system of equations;

$$\boldsymbol{\eta} = \mathbf{B}\boldsymbol{\eta} + \boldsymbol{\Gamma}\mathbf{X} + \boldsymbol{\zeta} \qquad (6)$$

where the matrix **B** shows the interaction among the latent variables present in the model, $\boldsymbol{\Gamma}$ shows the relationship between the latent and the exogenous variables and $\boldsymbol{\zeta}$ follows a multivariate normal distribution. The dimension of $\boldsymbol{\eta}$, $\mathbf{B}$, $\boldsymbol{\Gamma}$ and $\boldsymbol{\zeta}$ depends on the number of latent variables used in the model and the way exogenous variables affect them, as will be described in detail in the following paragraphs.

Variables η_u and η_b are unobserved, and in this modeling context are inferred from a set of stated preferences and perceptions towards ethanol usage. The variables that we use to capture stated preference and perceptions are the indicator variables (Y's). The indicator variable Y_u indicates the individual's stated intention of buying E10 instead of regular gasoline for a given price, i.e., $Y_u = 1$ when $\eta_u > 0$ and $Y_u = 0$ otherwise (this is the standard RUM assumption).

Three sets of survey questions (the perception indicators) were asked to elicit ethanol benefit (η_b) measures at three cognition levels: general (cognition level 1), intermediate (cognition level 2), and specific (cognition level 3). A single question was asked at the general level: "Would using E10 instead of conventional gasoline to run your vehicle give you more overall satisfaction?" (Y_G). At the intermediate level, three questions were asked about the impact of increased ethanol use on the economy, the environment, and national security ($Y_{I,ECON}$, $Y_{I,GREEN}$, $Y_{I,GUNS}$). At the specific level, nine questions were asked, three each on environmental ($\vec{\mathbf{Y}}_{S,GREEN}$), economic ($\vec{\mathbf{Y}}_{S,ECON}$), and national security issues ($\vec{\mathbf{Y}}_{S,GUNS}$), such as, one element of the vector $\vec{\mathbf{Y}}_{S,ENVI}$ is, "How will ethanol use affect the nation's greenhouse gas emissions?"

Each continuous latent variable (η) is related to the respective indicator variables (**Y**) through probit-type regression. For example, η_u is mapped onto Y_u (which is binary) through probit regression and the rest of the η's are mapped onto the respective indicator variables (which are ordered categorical[1]) through ordered probit regressions. Remember that this model assumes relationship among the latent variables, e.g. utility differential and other perceptions, and not among the respective indicators. The relationships among the latent variables are linear, while the relationship among the respective indicator variables would have been non-linear.

Based on the ways these perception indicators are used, we developed 9 variants of the general model (hereafter called models). These models can be divided into two categories; cognition level-independent (Models 1 to 6), where we derive estimates using perception information at each cognition level without regard to information at other cognition levels; and cognition level-interdependent (Models 7 to 9), where perceptions at one level are used to explain perceptions at another level. For example, in model 5 the three intermediate cognition-level indicator variables are used to measure the impact of perception on WTP for E10, while in model 8, the three intermediate cognition-level indicator variables are used to predict the general perception variable (Y_G) which in turn affects the WTP. Furthermore, the models could be grouped according to model structure. Models 1, 2, and 3 are single equation models. In these models, we estimate mean WTP for E10 using single equation and ignore the possible endogeneity or heterogeneity of the perception variables. The remaining 6 models allow heterogeneity in perception indicators. Table 1 shows the nine models according to cognition-level relationship and modeling approach, their structure, the indicator variables used to capture the respective latent variables, and Table 2 shows the corresponding survey questions and the summary statistics. We employ limited information maximum likelihood estimators for model

[1] In our survey, the perception indicator variables are ordinal (ordered categorical) in nature because the survey responses were measured on a Likert scale.

estimation, based on the method developed by Muthen (1983, 1987, 1989), and estimation was carried in MPlus version 4.0.

Table 1: Model Representation[2]

Cognitive-level independent	**Cognitive-level interdependent**
(1): $Y_U = f(\mathbf{X}_u, Y_G)$	**(7):** $Y_U = f(\mathbf{X}_u, Y_G)$; $Y_G = g(\mathbf{X}_b, Y_{I, ECON}, Y_{I,GREEN}, Y_{I, GUNS})$
(2): $Y_U = f(\mathbf{X}_u, \vec{\mathbf{Y}}_I)$	
(3): $Y_U = g(\mathbf{X}_U, \vec{\mathbf{Y}}_{S, ECON}, \vec{\mathbf{Y}}_{S, GREEN}, \vec{\mathbf{Y}}_{S, GUNS})$	**(8):** $Y_U = f(\mathbf{X}_u, Y_G)$; $Y_G = g(\mathbf{X}_b, \vec{\mathbf{Y}}_{S, ECON}, \vec{\mathbf{Y}}_{S, GREEN}, \vec{\mathbf{Y}}_{S, GUNS})$
(4): $Y_U = f(\mathbf{X}_u, Y_G)$ $Y_G = g(\mathbf{X}_b)$	**(9):** $Y_U = f(\mathbf{X}_u, Y_{I, ECON}, Y_{I,GREEN}, Y_{I, GUNS})$ $Y_{I, ECON} = g(\mathbf{X}_{ECON}, \vec{\mathbf{Y}}_{S, ECON})$; $Y_{I,GREEN} = g(\mathbf{X}_{GREEN}, \vec{\mathbf{Y}}_{S, GREEN})$; $Y_{I, GUNS} = g(\mathbf{X}_{GUNS}, \vec{\mathbf{Y}}_{S, GUNS})$;
(5): $Y_U = f(\mathbf{X}_u, \vec{\mathbf{Y}}_I)$ $Y_{I, ECON} = g(\mathbf{X}_{ECON})$ $Y_{I, GREEN} = g(\mathbf{X}_{GREEN})$ $Y_{I, GUNS} = g(\mathbf{X}_{GUNS})$	
(6): $Y_U = f(\mathbf{X}_u, \vec{\mathbf{Y}}_{S, ECON}, \vec{\mathbf{Y}}_{S, ENVI}, \vec{\mathbf{Y}}_{S, GUNS})$ $\vec{\mathbf{Y}}_{S, ECON} = \mathbf{g}(\mathbf{X}_{ECON})$ $\vec{\mathbf{Y}}_{S, ENVI} = \mathbf{g}(\mathbf{X}_{GREEN})$ $\vec{\mathbf{Y}}_{S, GUNS} = \mathbf{g}(\mathbf{X}_{GUNS})$	

[2] The above table is only for representational purposes. The actual modeling takes place among the latent variables underlying each of the indicators. For example, in model 4, $\eta_U = f(\mathbf{X}_u, \eta_G)$, $\eta_G = g(\mathbf{X}_b)$, and η_U is mapped onto Y_U through probit regression and η_G is mapped onto Y_G through ordered probit regression.

Table 2: Summary Statistics of Perception Indicator and other variables. Perception indicators are captured on a 3-point Likert scale of 1 to 3, where higher value indicates more positive perception.

Perception Indicator	Questions asked in the Survey	Frequency	Mean	Std. dev
Y_G	Would using E10 instead of conventional gasoline to run vehicle give you more overall satisfaction?	657	1.843	0.867
$Y_{I, ECON}$	*Compared to gasoline*, the impact of increased usage of E10 on the economy would be …	638	2.608	0.624
$Y_{I, ENVI}$	*Compared to gasoline*, the impact of increased usage of E10 on the environment would be…	633	2.480	0.700
$Y_{I, GUNS}$	*Compared to gasoline*, the impact of increased usage of E10 on the national security would be…	623	2.528	0.525
$\vec{\mathbf{Y}}_{S,ECON}$	1. How will ethanol use affect rural sector jobs?	653	2.568	0.554
	2. How will ethanol use affect urban sector jobs?	648	2.170	0.454
	3. How will use of ethanol affect the price of gasoline and other petroleum products?	654	2.087	0.700
$\vec{\mathbf{Y}}_{S,ENVI}$	1. How will ethanol use affect nation's soil and water quality?	659	1.932	0.712
	2. How will ethanol use affect net energy delivered?	651	1.779	0.719
	3. How will ethanol use affect nation's greenhouse gas emissions?	657	2.457	0.619
$\vec{Y}_{S,GUNS}$	1. How will ethanol use affect nation's crude oil import from Mid-eastern countries?	660	2.511	0.636
	2. How will ethanol use affect nation's crude oil import from other than Mid-eastern countries?	659	2.399	0.652
	3. How will ethanol use affect nation's expenditure on national security?	654	1.953	0.561
Y_U	WTP question (1 = pay premium for E10, 0 = buy regular gasoline)	650	.243	0.429
	vehicles own	658	2.16	1.15
	gasoline price most recently paid	631	2.99	0.32
	Area live (base = not big city)	655	0.36	0.48
	Gender (Baseline = Male)	663	0.31	0.47
	familiarity with ethanol	661	1.65	0.79
	Mid-west corn producing states	748	0.21	0.40
	Age	734	2.43	0.61
	Education	662	1.68	0.81
	Income	622	3.68	1.55

3. Survey methods and data description:

Although ethanol represents less than 4 percent of today's domestic gasoline market, and is expected to comprise still less than 8 percent by the year 2017 (USDA, 2007), ethanol has become a lightning rod for a variety of hot-button issues like national security, climate change, agricultural production and conservation, and fuel prices; and interestingly, it is still not clear whether ethanol represents a net gain or loss on most of these issues. Yet in spite of the surge in its production – an almost 200% increase since 2000 (RFA, 2007) -- and its apparent key role in discussions of these issues, very little work has been done to understand ethanol demand.

In order to collect the required data for the study, we designed a contingent valuation (CV) mail survey. The survey was sent out between April and June of 2007. A stratified (weighted by state population) random samples of 3,000 persons were selected across all 50 states and Washington, D.C. The sample was further divided into 6 independent stratified (weighted by state population) samples of 500 persons based on question ordering (2) and respondent incentive (3). In one ordering, the WTP question follows the detailed perception questions on ($\vec{\mathbf{Y}}_{S, ECON}$, $\vec{\mathbf{Y}}_{S, GREEN}$ and $\vec{\mathbf{Y}}_{S, GUNS}$) and in the other set the sequence was reversed . The primary reasons for doing this was to observe whether the relationship between general perception ($Y_{I, ECON}$, $Y_{I, ENVI}$ and $Y_{I\ GUNS}$) and perceptions captured by asking more detailed questions ($\vec{\mathbf{Y}}_{S, ECON}$, $\vec{\mathbf{Y}}_{S, GREEN}$ and $\vec{\mathbf{Y}}_{S, GUNS}$) is moderated by the presence of WTP question. The sample was split in three according to the incentive offered to encourage a response: no incentive, \$1 included with the survey, and \$5 conditional upon return of the survey.

In the WTP question, we asked each respondent whether s/he would be willing to pay $\$P_{E10}$ for E-10, where $\$P_{E10}$ is the "energy-equivalent price" plus a premium (p), or choose regular gasoline at price $\$P_{GAS}$. The energy-equivalent price is based on the Department of Energy's conversion yield of 1.52 times more mileage per gallon of regular gasoline than 100%

ethanol (DOE, 2005). The price of regular gasoline was held constant at \$2.55/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 E10 was calculated as \$2.55[0.9 + (0.1/1.52)] = \$2.46. Added to this amount was a randomly-assigned premium of 5, 10, 15, 20, or 25¢/gal to arrive at the stated E10 price, P_{E10}. Respondent understanding of the energy-equivalent price was critical; thus we gave detailed information about energy-equivalence and its relationship to price and included questions to confirm their understanding.

As mentioned in the previous section, the survey included a set of questions to elicit consumer's benefit perception at three cognitive levels: 1) overall satisfaction (Y_G); 2) economic, environmental, and national-security perceptions in general ($Y_{I,\,ECON}$, $Y_{I\,GREEN}$ and $Y_{I,\,GUNS}$); and 3) economic, environmental, and national-security perceptions with specific details ($\vec{\mathbf{Y}}_{S,\,ECON}$, $\vec{\mathbf{Y}}_{S,\,GREEN}$ and $\vec{\mathbf{Y}}_{S,\,GUNS}$). For example, $\vec{\mathbf{Y}}_{S,\,GREEN}$ is comprised of questions on soil and water quality, net energy and greenhouse gas effect of ethanol use, respectively. Similarly, we ask set of questions $\vec{\mathbf{Y}}_{S,\,GREEN}$ and $\vec{\mathbf{Y}}_{S,\,GUNS}$ to understand individuals' perception about economic and political impact of ethanol use at a deeper level.

The survey generated 748 returns; the \$1 incentive appears to have been the most effective, as 311 of the total were from that group; 235 were from the \$5 group; and 202 from the no-incentive group. Out of 748 returns, 158 respondents stated that they were willing to pay some premium for E10, 492 said they were not, and 98 did not respond to the WTP question. Of the 492 that said they were not willing to pay, 171 stated they would not buy E10 at any price (protest votes). The majority of non-respondents to the WTP question did not reply to other survey questions either. Respondents were asked to choose from a set of alternatives what they thought was the best approach to reducing gasoline dependence in this country: 310 chose an increase in the use of electric, fuel-cell, and/or hybrid vehicles; 152 chose increased use of public transportation; and 152 chose increased ethanol use.

5. Results:

5.1 Evaluation of Models

Models 1-3 are most likely to suffer from endogeneity bias. However, among them, model 1 has the best fit. The remaining 6 simultaneous models (4-9), we evaluated on information criteria. Table 3 also shows the overall explanatory power of higher level cognitive variables to lower-level cognitive variables.

Table 3: Information Criteria

Model No.	No. of Parameters	AIC	BIC	SBIC	R^2 for Y_G	R^2 for Y_U
1	17	421.5	493.01	439.05		0.536
2	19	442.32	521.34	461.04		0.439
3	25	462.16	566.08	486.74		0.385
4	**25**	**1454.38**	**1559.54**	**1480.19**	**0.047**	**0.608**
5	37	2738.62	2892.5	2775.07		0.501
6	88	7994.34	8360.15	8080.86		0.409
7	**28**	**1282.56**	**1398.96**	**1310.09**	**0.284**	**0.656**
8	**34**	**1317.87**	**1459.14**	**1351.23**	**0.252**	**0.645**
9	46	2471.6	2660.63	2514.64		0.53

Model 7 looks best according to AIC, BIC and SBIC information criteria (where the lower value indicates the better fit). It also has the highest R^2 value for Y_G and Y_U. Results also indicate that the intermediate perceptions explain more of overall perception (η_G) in comparison to specific-level perceptions. It is interesting to note that there were only 3 indicators to capture intermediate-level perceptions, whereas we have 9 indicators to capture specific-level perception. As the number of questions to capture perceptions increases, the indicators lose explanatory power, possibly because of cognitive burdens to the individuals. Hereafter, we focus mainly on Models 1 and 7.

5.1 Analysis of results

Table 4 shows the results of Models 1 and 7. These two models behave in somewhat similar fashion: intercept term, perceived benefit, bid values, familiarity with ethanol, gender and political orientation are significant in both models; self-described liberals have significantly higher WTP; WTP is higher for males; and WTP increases as familiarity with ethanol increases. Supporters of alternative fuels, but who are not sympathetic to ethanol, have significantly lower WTP for E10. Overall perceived benefit from ethanol usage (η_G) is significantly influenced by an individual's gender and alternative fuel preferences. Those who support increased usage of public transport or electric and/or hybrid vehicles, but not ethanol, perceive significantly lower benefits from ethanol usage. The primary difference between Models 1 and 7 is the difference in mean WTP. Mean WTP is calculated as the ratio of intercept and price-coefficient of WTP equation. The single equation model (model 1) results in a lower WTP. It puts relatively more weight on the price coefficient as a result of model misspecifications. As we introduce more significant variables into the model, mean WTP should increase. The mean WTP value is almost similar across models 4, 7 and 8 (appendix 1). All three models assume Y_G as the representative indicator for benefit-perception in the WTP question. Our findings also concur with earlier findings by Whitehead. The results show that the mean WTP for E10 is almost .049 cents higher than the prevailing national average price of regular gasoline during the time of survey ($2.55/gallon,). The other three simultaneous models, i.e. model 5, 6 and 9 (appendix 1) gave similar value of WTP. However, the mean WTP for these models are lower than those of Models 4, 7 and 8. The weaker explanatory power of the perception variables in the WTP equation are the primary reasons for having lower mean WTP in these models.

Table 5 shows that the general perception does not vary much as the exogenous variables vary. Rather it is better explained by other higher-level perception indicators, in particular, the intermediate-level perceptions. We see that individuals who have positive feelings about the impacts of ethanol usage on the environment, the economy and national security are more inclined to pay a premium for E10. However, although the intermediate-level perception for national security ($Y_{I, GUNS}$) explains Y_G significantly, $\vec{\mathbf{Y}}_{S, GUNS}$, the set of questions supposed to capture the national security issues in greater details, could not explain Y_G at all. It appears that individuals are more concerned about overall price effect. While concern about greenhouse gas emissions and energy requirements to produce E10 shapes an individual's general perception toward the benefit of E10 over regular gasoline, their perceptions are not influenced significantly by the possible impact of ethanol usage on soil and water quality. While general perception does not vary much, the intermediate-level perceptions vary significantly as the exogenous variables vary. Table 6 shows the regression results of intermediate-level perceptions on other exogenous variables and specific-level perceptions. The table shows that supporter of alternative fuels, but who are not sympathetic to ethanol; perceive ethanol use will be having adverse effect on environment and economy. Additionally, older people perceive less economic benefit from ethanol use. Explanatory power of exogenous variables changes drastically as we add specific-level perceptions to explain intermediate-level perceptions.

Table 4: Estimation results

	Model 7	Model 1
Mean WTP ($)	2.594	2.441
Bid	-6.814***	-6.905***
Intercept	-17.674***	-16.857***
vehicles own	0.023	0.022
gasoline price most recently paid	-0.272	-0.285
Area live (base = not big city)	0.257	0.212
public transport supporter	-0.580***	-0.479**
alternative fuel but not ethanol supporter	-0.451***	-0.394**
Gender (Baseline = Male)	-0.587***	-0.514***
familiarity with ethanol	-0.157	-0.149
Mid-west corn producing states	0.19	0.182
Age	-0.102	-0.097
Education	-0.029	-0.026
Income	0.017	0.012
conservative	0.212	0.147
Liberal	0.831***	0.729***
Group1	0.264*	0.233
Y_G	0.919***	0.944***

*** Significant at 1% level
**Significant at 5 % level
*Significant at 10 % level

Table 5: Regression results for general-level perceptions

	cognitive-level interdependent		cognitive-level independent
	Y_G on specific indicators	Y_G on intermediate indicators	Y_G on exogenous variable only
number of vehicles own	0.017	0.062	0.036
$Y_{S,GREEN1}$	0.089		
$Y_{S,GREEN2}$	0.258***		
$Y_{S,GREEN3}$	0.289***		
$Y_{S,ECON1}$	0.386***		
$Y_{S,ECON2}$	-0.023		
$Y_{S,ECON3}$	0.264***		
$Y_{S,GUNS1}$	0.227		
$Y_{S,GUNS2}$	-0.064		
$Y_{S,GUNS3}$	0.142		
$Y_{I,GREEN}$		0.565***	
$Y_{I, ECON}$		0.279***	
$Y_{I, GUNS}$		0.413***	
public transport supporter	0.034	0.028	-0.245
alternative fuel but not ethanol supporter	0.162	0.109	-0.045
Gender (Baseline = Male)	-0.186	-0.135	-0.366***
familiarity with ethanol		-0.081	-0.099
Age	0.021		
conservative			
Liberal	0.145	0.116	0.213

*** Significant at 1% level
** Significant at 5 % level
* Significant at 10 % level

Table 6: Regression results for intermediate-level perceptions

Independent variable	cognitive-level interdependent			cognitive-level interdependent		
	$Y_{I,GREEN}$	$Y_{I,ECON}$	$Y_{I,GUNS}$	$Y_{I, GREEN}$	$Y_{I, ECON}$	$Y_{I, GUNS}$
number of vehicles own		0.01			0.068	
$Y_{S,GREEN1}$	0.338***					
$Y_{S,GREEN2}$	0.425***					
$Y_{S,GREEN3}$	0.646***					
$Y_{S,ECON1}$		0.196*				
$Y_{S,ECON2}$		0.385***				
$Y_{S,ECON3}$		0.379***				
$Y_{S,GUNS1}$			0.266*			
$Y_{S,GUNS2}$			-0.195			
$Y_{S,GUNS3}$			0.260**			
public transport supporter	-0.266	-0.564***	-0.109	-0.532***	-0.654***	-0.206
alternative fuel but not ethanol supporter	-0.05	-0.428		-0.327**	-0.482***	
Gender (Baseline = Male)	-0.261*	-0.366***	-0.453***	-0.444***	-0.446***	-0.496***
familiarity with ethanol			-0.102			-0.109
Age		-0.129			-0.167*	
conservative		-0.204*			-0.205*	

*** Significant at 1% level
** Significant at 5 % level
* Significant at 10 % level

Conclusion:

This study contributes to the ongoing economic research on US demand for ethanol in various ways. First of all, it provides a representative figure about individuals' mean willingness to pay premium for E10 fuel over regular gasoline. Secondly, the study helps us to know the influencing factors behind US demand for ethanol. We found self-described liberals have significantly higher WTP; WTP is higher for males; and also increases as familiarity with ethanol increases. Supporters of alternative fuels, but who are not sympathetic to ethanol, have significantly lower WTP for E10. Overall perceived benefit from ethanol usage is significantly influenced by an individual's gender and alternative fuel preferences. Those who support increased usage of public transport or electric and/or hybrid vehicles, but not ethanol, perceive significantly lower benefits from ethanol usage. Concerns about economy and environment rather than national security shape individuals' overall perception towards ethanol use.

Ben-Akiva et al (2002) discussed the importance of predictive choice models that go beyond the archetypal random utility model framework. They incorporate several elements of cognitive process that have been identified as important to the choice process, including strong dependence on history and context, perception formation, and latent constraints. Whitehead (2006) showed that inability to capture heterogeneity in perception variable results in biased willingness to pay value. However, his model dealt with one indicator variable to capture perception. Usually in a CVM study, researchers employ multiple indicators to capture individuals' perception about the choice of interest, and it is likely that those perceptions vary across individuals. Our proposed simultaneous latent variable framework facilitates modeling of willingness to pay model while capturing the heterogeneity in various perceptions. Also, the simultaneous latent variable framework helps us to understand the way consumer's' perceptions are developed and influence their economic behavior towards E10 fuel. It shows the relationship and the importance of human cognizance at various levels. As we found, asking too many questions may in fact might not to very helpful to understand individuals' overall perception.

References:

Ben-Akiva, Moshe et. al.(2002), "Hybrid Choice Models: Progress and Challenges." *Marketing Letters* 13(3):163-175.

Danielson, Leon, Thomas J. Hoban, George Van Houtven, and John C. Whitehead. (1995), "Measuring the benefits of local public goods: Environmental quality in Gaston County, North Carolina.", *Applied Economics*, 27:1253-60.

Haab, Timothy C. and McConnell, Kenneth E., "Valuing Environmental and Natural Resources: The Econometrics of Non-Market Valuation", Edward Elgar Publishers, Cheltenham, UK

Kahn, Matthew E. (2007), "Do greens drive Hummers or hybrids? Environmental ideology as a determinant of consumer choice", *Journal of Environmental Economics and Management*, Volume 54, Issue 2, September, Pages 129-145

Kotchen, M. and Moore, M. (2007), "Private provision of environmental public goods: household participation in green-electricity programs", *Journal of Environmental Economics and Management*, 53, pp. 1–16.

Muthén, B. (1983), "Latent variable structural equation modeling with categorical data" *Journal of Econometrics*, 22, 48-65.

Muthén, B. (1984), "A general structural equation model with dichotomous, ordered categorical, and continuous latent variable indicators", *Psychometrika*, 49, 115-132.

Muthén, B.(1989), "Latent variable modeling in heterogeneous populations", *Psychometrika*, 54, 557-585.

Muthén, L. K., & Muthén, B.2004, "*Statistical Analysis with latent variables. Mplus: User's guide*", Los Angeles, CA: Muthén & Muthé

Whitehead, John C. (2006), "Improving Willingness to Pay Estimates for Quality Improvements through Joint Estimation with Quality Perceptions", *Southern Economic Journal,* 73(1). 100-111

Appendix 1: Estimation results of the remaining models

Model No.	9	8	6	5	4	3	2
Mean WTP	2.505	2.576	2.500	2.50	2.578	2.331	2.395
Bid	-5.980***	-6.844***	-6.173***	-6.013***	-6.905***	-6.173***	-6.013***
Intercept	-14.979***	-17.633***	-15.432***	-15.272***	-17.802***	-14.392***	-14.399***
Vehicles own	0.013	0.012	0.022	0.03	0.022	0.022	0.03
Gasoline price most recently paid	-0.114	-0.277	-0.116	-0.177	-0.285	-0.116	-0.177
Area live (base = not big city)	0.228	0.224	0.16	0.235	0.212	0.16	0.235
public transport supporter	-0.444**	-0.514***	-0.422*	-0.456**	-0.479**	-0.422**	-0.456***
alternative fuel but not ethanol supporter	-0.278	-0.391**	-0.228	-0.292*	-0.394**	-0.228	-0.292*
Gender (Baseline = Male)	-0.545***	-0.500***	-0.496***	-0.577***	-0.514***	-0.496***	-0.577***
familiarity with ethanol	-0.270**	-0.141	-0.262***	-0.280***	-0.149	-0.262***	-0.280***
Mid-west corn producing states	0.009	0.183	0.1	0.027	0.182	0.1	0.026
Age	-0.108	-0.114	-0.014	-0.099	-0.097	-0.014	-0.099
Education	0.063	-0.011	0.071	0.054	-0.026	0.071	0.054
Income	0.017	0.015	0.004	0.017	0.012	0.004	0.017
conservative	0.148	0.1	0.106	0.198	0.147	0.106	0.198
Liberal	0.636***	0.645***	0.577***	0.693***	0.729***	0.577***	0.693***
Group1	0.195	0.290*	0.084	0.155	0.233	0.084	0.155
Y_G		0.928***			0.944***		
$Y_{I,GREEN}$	0.386**			0.392**			0.392***
$Y_{I, ECON}$	0.445***			0.452***			0.452***
$Y_{I, GUNS}$	0.042			0.028			0.028
$Y_{S,ECON1}$			0.055			0.055	
$Y_{S,ECON2}$			-0.005			-0.005	
$Y_{S,ECON3}$			0.039			0.039	
$Y_{S,GREEN1}$			-0.014			-0.014	
$Y_{S,GREEN2}$			0.343***			0.343***	
$Y_{S,GREEN3}$			0.217			0.217	
$Y_{S,GUNS1}$			0.055			0.055	
$Y_{S,GUNS2}$			0.153			0.153	
$Y_{S,GUNS3}$			0.197			0.197	