Consumer Preferences for Second-Generation Bioethanol

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CONSUMER PREFERENCES FOR SECOND-GENERATION BIOETHANOL

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Abstract: In this study, we investigate the consumer response toward fuel from second-generation, nature-inspired lignocellulose processing systems. We conduct consumer surveys with two different information treatments. We utilize a dichotomous-choice contingent valuation methodology to estimate willingness to pay for this product and analyze factors that affect consumer choice. The results suggest that the average respondent is willing to purchase second-generation bioethanol with a 4% discount compared to conventional fuel. Some demographic variables and driving behavior are found to have significant effects on consumer willingness to pay. The effect of information regarding the second-generation, nature-inspired lignocellulose process is found to be insignificant.

JEL Classifications: C25, C83, D12, Q16

Keywords: Consumer Preferences; Second-generation Bioethanol; Contingent Valuation

Introduction

The United States consumes more petroleum fuel per capita than any other OECD country, and the transportation sector accounts for 70 percent of U.S. oil consumption and 30 percent of U.S. greenhouse gas (GHG) emissions (Knittel, 2012). Biofuels gain attention for seeking to reduce the consumption of petroleum-based liquid fuel. Many researchers argue that consumer valuation of technologies needs to be studied in order to effectively develop the renewable energy market (e.g., Zarnikau, 2003; Collantes, 2010).

A major barrier to growth of the biofuel industry is the lack of an effective process that transforms lignocellulosic biomass to simple sugar molecules for production of biofuel and bioproduct. First-generation bioethanol is produced from corn, rice and other grains, and so producing first-generation ethanol can increase food prices. Second-generation bioethanol (cellulosic ethanol) has a lower impact on food prices because it is made from weeds, straw, and other agricultural residues, which can be grown on marginal lands. Nature-inspired second-generation bioethanol uses termites to convert wood waste into usable fuel. Nature-inspired lignocellulose processing systems are more energy efficient, environmentally sustainable and economically feasible than the existing thermochemically-based technologies.

In this study, we investigate consumer preferences for fuel from nature-inspired lignocellulose processing systems compared to existing thermochemically-based technologies. To this end, we conduct analyses of consumer acceptance and willingness to pay (WTP) in order to estimate profitability of the proposed biologically inspired energy system. We utilize a contingent valuation (CV) approach, which is a survey-based economic valuation technique, in order to measure consumer's WTP for this product. In addition, we examine whether the provision of information describing the advantages of nature-inspired lignocelluloses processing systems has a significant effect on consumers' WTP. In total, 200 consumers were surveyed for the purpose of this study in Portland, Oregon. The survey data includes information about consumers' driving habits, attitudes, and demographic characteristics. It also contains the responses to dichotomous choice questions that were intended to elicit the respondents' WTP. We utilize a double-bounded dichotomous choice model to evaluate the responses.

The results of this study suggest that 31% of the surveyed consumers are willing to purchase second-generation bioethanol at a premium price and 48% more at the current market price. We estimate that, on average, consumers are willing to purchase this product with a 4% discount over conventional fuel.

Previous Literature

Some papers investigate public attitudes toward renewable fuels. Ulmer et al. (2004) conduct a mail survey in Oklahoma and find that, in their decision to purchase an ethanol blend, consumers value cost, environmental impact and vehicle performance in a descending order. They suggest that neither of gender, education, income, age, nor urban or rural location of household has correlation with willingness to purchase an ethanol blend. Li et al. (2009), combine a telephone survey and an online survey, show that U.S. household are generally willing to fund research and development for renewable energy sources. The willingness to pay (WTP) is higher for females, liberals and those with higher incomes. Solomon and Johnson (2009) conduct a survey in Michigan, Minnesota and Wisconsin to estimate WTP for cellulosic ethanol. They conclude that a large proportion of respondents are willing to pay an extra for cellulosic ethanol than gasoline. Using face to face interviews in Greece, Savvanidou et al. (2012) find that half of the respondents believe biofuel can effectively ameliorate climatic changes and energy problem.

However, there is a severe lack of information about biofuels, especially among young or low education people.

Recently, scientific research starts to link ethanol production to environmental damage. For example, Timilsina & Shrestha (2011) argue that biofuels reduce GHG emissions only if GHG emissions related to land-use change are avoided. The environmental friendliness of biofuel is different across inputs, and previous research suggests that consumers' WTP for renewable energy varies by source (e.g., Borchers & Parsons, 2007). Several studies start to examine consumer valuation on specific properties of renewable fuels. Van de Velde et al., (2009) find that fuel price, quality, availability in fuel stations and environmental friendliness are considered very important in fuel choice by the respondents in Belgian. Petrolia et al., (2010) conduct a nationwide survey of consumer preferences for E10 and E85. The estimated mean WTP for E10 ranges from 6.2 to 12.4 cents per gallon depending on the econometric method used, while the mean WTP for E85 is from 13.1 to 15.2 cents per gallon. Jensen et al. (2010) show that respondents' WTP for E85 from switchgrass is nearly 1 cent per mile greater than E10 from corn. Concerns about land use have a negative impact on WTP for food-based ethanol, but concerns about fuel security have a positive impact.

Data

A consumer survey was conducted in February 2014 at the Portland Auto Show in Portland, Oregon. The interviewers randomly picked respondents from busy spots at the show. For each questionnaire, 10 to 15 minutes were needed for completion. In total 200 valid face-to-face interviews were analyzed. The survey solicited information regarding respondent's driving habits, environmental friendliness, and demographic information.

The demographic characteristics of the respondents are summarized in Table 1. The average age is around 40 years, with a minimum age of 15 years and a maximum age of 78 years. Twenty-four percent of the respondents have at least one child less than 18 years living with them. There are 58.5% male and 41.5% female participants in the study sample, and there is diversity in terms of ethnic affiliations of the respondents interviewed during this survey. The study sample comprised of 80.5% Whites (not Hispanics), 2% African-Americans, 8.5% Asians, 4% Hispanics, and 4% mixed/others ethnic groups. The education level of the respondents summarized shows that there are 17.5% advanced degree or graduate degree holders, 28.5% Bachelors' degree holders, 42.5% with some college degree, and 8.5% with high school diploma. The employment status of the respondents indicate that 53.5% of the respondents are employed, 20.5% are self-employed, 3% are unemployed, 9% are retired, 10.5% are students, and 3.5% stay at home (parent/caregiver). There are 14% respondents in 'less than $20,000' income group, 28% in '$20,000 to $39,999' income group, 27.5% in '$40,000 to $59,999' income group, 12.5% in '$60,000 to $79,999' income group, 7% in '$80,000 to $99,999' income group, and 10% in '$100,000 or more' income group.

The results in Table 2 summarize the driving habits and other driving related characteristics of the survey respondents. Twenty-six percent of the respondents own 1 car, 34.5% of the respondents own 2 cars, and 38.5% of the respondents own more than two cars. The participants reported that 21.5% of them use premium gasoline, with others using regular gasoline. Further, the survey participants reported miles they travel per annum: 11% drive "less than 5000 miles per year", 28.5% drive "between 5000 to 10000 miles per year", 32.5% drive "between 10000 to 15000 miles per year", 15% drive "between 15000 to 20000 miles per year", and 13% drive "more than 20000 miles per year". It is observed that there are 65% respondents with some knowledge about renewable energy sources, 17% respondents with no knowledge about the renewable source, and 18% respondents with high knowledge about renewable energy sources. The response of the participants about the importance of higher environmental friendliness of fuel, compared to buying fuel at the lowest price indicate that majority of them are more inclined towards environmental friendliness.

Methodology

For this study, we utilize the contingent valuation (CV) method to estimate WTP for nature-inspired lignocellulose processing systems and analyze factors that affect consumers' choices. This technique is widely used for estimating individual WTP based on the responses of market-type questions with dichotomous choices (Kanninen, 1993; Venkatachalam, 2004). In our study, consumers answer dichotomous choice bid questions s to measure their WTP for fuel from nature-inspired lignocellulose processing systems. Each respondent is asked if he or she is willing to purchase fuel from nature-inspired lignocellulose processing systems at a specified price, which we refer to as the initial bid. If the answer is "yes," then the respondent is asked whether he or she is willing to purchase the nature-inspired lignocellulose fuel at a higher price. Alternatively, if the answer to the initial bid question is "no," then the respondent is asked whether he or she is willing to purchase the nature-inspired lignocellulose fuel at a discounted price. One of four premiums (5%, 10%, 20% and 30%) or discounts (5%, 10%, 20% and 30%) is randomly assigned to each respondent. Table 3 displays the distribution of bid responses.

We use a double-bounded dichotomous choice model to evaluate the respondents' outcomes from our survey (Hanemann et al., 1991; Venkatachalam, 2004). This model is asymptotically more efficient compared to the single-bounded model. However, Hanemann et al. (1991) report that the double-bounded model may exhibit bias due to possible anchoring from the initial bid. However, later they point out that the bias is out-weighed by the gain in efficiency. In the current study, we use the current market price for fuel as the initial bid, which may serve as a natural anchor that consumers would be aware of even with a single-bounded model.

The responses to the CV questions results in four possible outcomes in double-bounded model: (1) the respondent is not willing to purchase nature-inspired lignocellulose fuel at the market price of conventional fuel and does not want to buy them even at the discount price (i.e., "no" to both bids); (2) the respondent is not willing to purchase fuel from nature-inspired lignocellulose processing systems at the market price of the existing thermochemically-based fuel but is willing to buy them at the discounted price (i.e. "no" followed by "yes"); (3) the respondent is willing to purchase fuel from nature-inspired lignocellulose processing systems at the market price of existing thermochemically-based fuel but is not willing to buy fuel from nature-inspired lignocellulose processing systems at the premium price (i.e. "yes" followed by "no"); (4) the respondent is willing to purchase fuel from nature-inspired lignocellulose processing systems at the market price for existing thermochemically-based fuel and also willing to purchase them at premium price (i.e. "yes" followed by "yes").

Using the double-bounded model with these four outcomes allows us to place the respondent's true WTP for fuel from nature-inspired lignocellulose processing systems into one of four intervals: $(-\infty, B_D)$, $[B_D, B_I)$, $[B_I, B_P)$ or $[B_P, +\infty)$ where B_D, B_I, and B_P are discounted, initial, and premium bids, respectively. The bidding mechanism results in the following discrete outcomes:

$$D = \begin{cases} 1 & WTP < B_D & (No, No) \\ 2 & B_D \leq WTP < B_I & (No, Yes) \\ 3 & B_I \leq WTP < B_P & (Yes, No) \\ 4 & B_P \leq WTP, & (Yes, Yes) \end{cases} \quad (1)$$

Where *WTP* is the respondent's WTP for fuel from nature-inspired lignocellulose processing systems. The individual WTP outcome is based on the random utility model where the respondent maximizes utility by choosing to purchase a product at the associated bid amount if the utility derived from this good is higher than from refusing the bid and foregoing the product. The probability of each outcome can be expressed as:

$$\Pr(Y = j) = \begin{Bmatrix} F(v(B_D, Z)) \\ F(v(B_I, Z)) - F(v(B_D, Z)) \\ F(v(B_P, Z)) - F(v(B_I, Z)) \\ 1 - F(v(B_P, Z)) \end{Bmatrix} \text{ for } j = \begin{Bmatrix} 1 \\ 2 \\ 3 \\ 4 \end{Bmatrix} \quad (2)$$

Where $F(\bullet)$ is a cumulative distribution function characterizing the random components of utility, *v(B,Z)* is the difference in indirect utility function between purchasing a product at bid B and declining the bid, and Z is a vector of characteristics that influence the indirect utility. The function *v(B,Z)* in (3) for the individual i can be written as

$$v\left(B_i, Z_i\right) = \alpha - \rho' B_i + \lambda' X_i, \quad i = 1, 2, \ldots, n \quad (3)$$

where B_i is the bid amount offered to respondents *i*, and X_i is the observable characteristics of the respondent *i*. α, ρ and λ are unknown parameters to be estimated. Then the log-likelihood function can be expressed as:

$$\ln L = \sum_{i=1}^{n} \begin{Bmatrix} I_{Y_{i=1}} \ln F(\alpha - \rho B_{Di} + \lambda' X_i) + \\ I_{Y_{i=2}} \ln[F(\alpha - \rho B_{Ii} + \lambda' X_i) - F(\alpha - \rho B_{Di} + \lambda' X_i)] + \\ I_{Y_{i=3}} \ln[F(\alpha - \rho B_{Pi} + \lambda' X_i) - F(\alpha - \rho B_{Ii} + \lambda' X_i)] + \\ I_{Y_{i=4}} \ln[1 - F(\alpha - \rho B_{Pi} + \lambda' X_i)] \end{Bmatrix} \tag{4}$$

Where $I_{Yi=j}$ is the indicators for each j outcomes (j=1,..,4) for the individual i. We define $F(\bullet)$ function to be the standard logistic distribution with mean zero and variance $\sigma^2 = (\pi / \sqrt{3})^2$. Then equation (3) can be written in the following empirical format:

$$\begin{aligned} v(B_i, Z_i) = \alpha - \rho B_i + \lambda_1 Info_i + \lambda_2 Demographics_i + \lambda_3 Engine_i \\ + \lambda_4 Environmental\ friendliness_i \end{aligned} \tag{5}$$

where B_i is the random bid offered to respondent i, $Info_i$ is a dummy variable indicating whether the respondent i received information about the product, $Demographics_i$ is a vector of variables representing the demographic characteristics of respondent i, $Engine_i$ is a vector of variables that represent respondent i's belief if the bioethanol is good for the car engine, and $Environmental\ friendliness_i$ is a vector of variables that represent how important does respondent i think of the environment friendliness of fuel. Table 4 displays a description and explanation of the explanatory variables used in the model.

Estimation Results

Table 5 presents the estimated marginal effects of the model variables with confidence intervals. Age has a significant influence on the probability of choosing fuel from nature-inspired lignocellulose processing systems. Unlike previous studies (see, for example, Grimsrud et al., 2004), older consumers are more likely to choose the product with new technology. Income has a negative influence on the WTP, which indicates that high-income groups are less likely to purchase second-generation bioethanol. If the individual has children younger than 18 in the household or drives more, she has a higher WTP. In addition, consistent with intuition, participants who are value environment more are more willing to purchase the product.

Based on previous studies, we expected for the information to have a positive effect on preferences the new technology but our results do not support this hypothesis. The variable representing the provision of information has statistically insignificant effect on WTP.

Next, we estimate the mean WTP calculated following Hanemann (1984) as $WTP = \frac{1}{\hat{\rho}}(\hat{\alpha} + \hat{Z}'\overline{X})$. The results suggest that in our sample, consumers, on average, are WTP 4% discount for fuel from nature-inspired lignocellulose processing systems compared to conventional fuel. We calculate the confidence intervals around the estimated mean WTP using the delta method (Greene, 2008). In percentage terms, the mean WTP for nature-inspired lignocellulose processing systems falls between 17% discount and 9% premium over conventional fuel.

We calculated the probability that the respondent choose to purchase fuel from nature-inspired lignocellulose processing systems. Figure 1 presents the probability of saying “yes” to this product given different levels of bids. The probability for the initial bid is 79%. The highest level of probability is 96% for a 30 percent discount and the lowest one is 14% for 20 percent premium.

Conclusions

Second-generation bioethanol is found to have a lower impact on food prices, and research on its development grows continuously. A better understanding of consumers' attitudes and behaviors toward second-generation ethanol is essential for designing market strategy for such product. In this study, we focus on consumers preferences toward nature-inspired bioethanol. Particularly, we analyze consumer WTP for it under different information treatments. The results suggest that 79% of the surveyed consumers are willing to purchase second-generation bioethanol at the current market price and 91% of them are willing to purchase it when a discount is offered.

Our results suggest that providing information about the product does not have a statistically significant effect on consumers WTP. It could be explained by the fact that 83% individuals in our sample are "somewhat knowledgeable" about biofuel. It is likely that they already have some knowledge about the product and, therefore, providing information has insignificant effect on their valuation toward it. In addition, we find that consumers who drive more have higher WTP for second-generation bioethanol. And participants who have children under 18 in their household are more willing to purchase the product.

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Table 1. The Summary Statistics for Demographic Variables

Number of respondents	200
Average age (years)	40.39
Variables	**Percentage of respondents**
Female	41.50%
Children under 18 present in household	24.00%
Education (highest level)	
Some School	3.00%
High school diploma	8.50%
Some college	42.50%
Bachelors' degree	28.50%
Advanced degree or graduate degree	17.50%
Household income (in 2013)	
Less than $20,000	14.00%
$20,000 to $39,999	28.00%
$40,000 to $59,999	27.50%
$60,000 to $79,999	12.50%
$80,000 to $99,999	7.00%
$100,000 or more	10.00%
Employment status	
Employed	53.50%
Self-employed	20.50%
Unemployed	3.00%
Retired	9.00%
Student	10.50%
Stay at home parent/ caregiver	3.50%
Racial/Ethniccal Identification	
White, not Hispanic	80.50%
African-American	2.00%
Asian	8.50%
Hispanic	4.00%
Mixed/ other	5.00%

Table 2. Distribution of Bid Responses.

Variables	Percentage of respondents
No. of cars	
One	26.00%
Two	34.50%
More than two	38.50%
Knowledge about renewable energy sources	
Very knowledgeable	18.00%
Somewhat knowledgeable	65.00%
Not knowledgeable	17.00%
Type of fuel	
Regular gasoline	78.50%
Premium gasoline	21.50%
Own or consider buying electric/hybrid vehicles	
Yes, I own	9.50%
Yes, I consider buying one	68.00%
No	22.50%
Miles driven per year	
Less than 5,000	11.00%
From 5,000 to 10,000	28.50%
From 10,000 to 15,000	32.50%
From 15,000 to 20,000	15.00%
More than 20,000	13.00%
Environmental friendliness	
1	11.50%
2	6.00%
3	12.00%
4	14.50%
5	14.00%
6	11.00%
7	12.00%
8	13.00%
9	3.50%
10	2.50%
Mean per gallon for gas purchased	$3.67
% of organic food purchased	
None	11.00%
1-25%	37.50%
25-50%	24.50%
50-75%	18.50%
75-100%	8.50%

Table 3. Distribution of Bid Responses.

	Premium				
	5%	10%	20%	30%	Total
Yes	27	14	7	14	62
No	23	34	44	37	138
Total	50	48	51	51	200
	Discount				
	5%	10%	20%	30%	Total
Yes	46	42	45	49	182
No	4	6	6	2	18
Total	50	48	51	51	200

Table 4. Description of Explanatory Variables

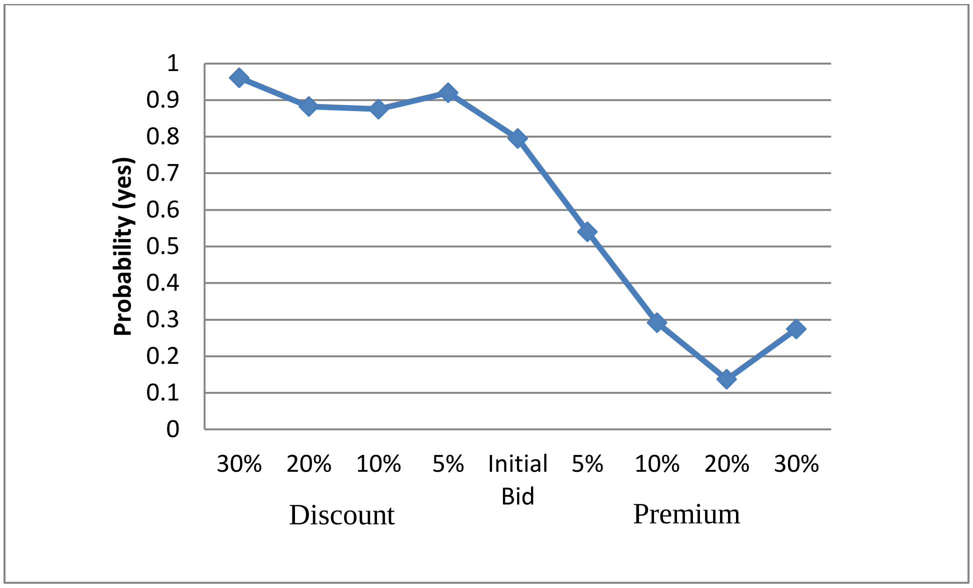
Variable	Description
Bid	Random bid offered to each respondent
Treatment	
Info	1 = Provision of positive information, 0 = no information
Knowledge about Renewable Energy Sources	
Knowledge	1 = Knowledgeable about renewable energy sources
Demographics	
Gender	1 = Female, 0 = Male
Education	1 = Bachelor's degree or above, 0 = otherwise
Income	1 = Last year's income is more than $80,000, 0 = otherwise
Age	Reported age
Child	1 = Present of child under 18 in the family, 0 = otherwise
Driving Distance	
High	1 = More than 15000 miles a year, 0 = otherwise
Fueling Preferences	
Environment - Price	Tradeoff between higher environmental friendliness and low price fuel, continuous scale of 1 = price most important to 10 = environment most important
Premium Gasoline	1 = Consumer mostly purchase premium gasoline, 0 = otherwise
Electric/hybrid	1 = Consumer owns electric/hybrid vehicle, 0 = otherwise
Engine	1 = Consumer believes that the product is good for car engine
Price for gas	Reported price of last purchased gas
Risk Preference	
Risk-lover	Consumer's willingness to take risks, continuous scale of 1 = completely unwilling to take risks to 10 = completely willing to take risks

Table 5. Marginal Effects of the Explanatory Variables on Mean WTP

Variable	Marginal Effect	Standard Error	Z-statistic	95% Confidence Interval	
				Lower Bound	**Upper Bound**
Constant	-	-	-	-	-
Bid	-	-	-	-	-
Information	-0.036	0.026	-1.39	-0.087	0.015
Gender (female)	0.030	0.026	1.16	-0.021	0.081
Education	-0.013	0.040	-0.32	-0.092	0.066
Income	-0.073**	0.035	-2.11	-0.140	-0.005
Age	0.002***	0.001	2.73	0.001	0.004
Child	0.100***	0.031	3.25	0.040	0.160
Driving High	0.063*	0.038	1.65	-0.012	0.137
Provision Advantage	0.107***	0.025	4.21	0.057	0.157
Non-white	0.046	0.031	1.47	-0.016	0.108
Risk-Lover	-0.004	0.007	-0.57	-0.017	0.010
Price for gas	-0.083	0.129	-0.64	-0.296	0.130
Constant	0.958***	0.067	14.31	0.827	1.090

Note: *10% significance level, **5% significance level, ***1% significance level.

Figure 1. Change in Estimated Probability of Choosing Second-generation Bioethanol given Bids.



Appendix. First-generation bioethanol is produced from corn, rice and other grains, and so producing first-generation ethanol can increase food prices. Second-generation bioethanol (cellulosic ethanol) has a lower impact on food prices because it is made from weeds, straw, and other agricultural residues, which can be grown on marginal lands.

Scientists at WSU are developing a nature-inspired second- generation bioethanol that uses termites to convert wood waste into usable fuel. Nature-inspired lignocellulose processing systems are more energy efficient, environmentally sustainable and economically feasible than the existing thermochemically-based technologies.