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Does Money Grow on Trees? People's Willingness to Pay for Cellulosic Wood Ethanol

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1. Introduction

According to the American Environment Research and Policy Center, America's dependence on fossil fuels, and the resulting global warming pollution, has been increasing both nationally and at the state level for decades (AERPC, 2009). The Intergovernmental Panel on Climate Change (IPCC, 2007) issued its Fourth Assessment Report in 2007, describing how atmospheric concentrations of carbon dioxide and other greenhouse gases have increased as a direct result of human activity for over one hundred years. Various implications of this increase in greenhouse gases include increases in average air and ocean temperatures, melting of snow and ice, and rising global average sea level. These environmental implications have important negative ecological and economic effects. Educational campaigns, policy initiatives and an increased public interest in alternative energies have led to the beginnings of a shift in this trend of increasing greenhouse gas emissions. Emissions declined in 17 states between 2004 and 2007 due to the use of cleaner and more efficient forms of energy (AERPC, 2009).

To continue this decrease in carbon emissions, it is in the interest of researchers and decision makers to expand the clean energy market, where doing so requires an understanding of the public's preferences and behavior regarding energy consumption. Attitudes are commonly linked to intentions and behavior, and as such, are believed to be an important component of the construction and implementation of various public policy initiatives (Krosnick, 1988; Ritchie & Spencer, 1994; Hini et al., 1995; Kaiser et al., 1999). Attitudes have been directly linked to behavioral change by Loudon and Della Bitta (1993), who state "behavioral change is a function of change in behavioral intentions...changes in behavioral intentions are related to change in attitude" (p.422), and by Bamberg (2003), who maintains that "degree of environmental concern has a direct strong impact on people's behavior" (p.4).

As a determinant of behavior, attitudes such as environmental concern are important to understand if we are to promote alternative energies like biofuels. Understanding whether or not environmental concern affects consumers' decisions to purchase biofuels will be of great use to policy makers and other groups interested in expanding the emerging biofuels market. On the other hand, consumer perceptions of biofuels are also likely to be important.

For example, Teisl et al. (2009) find that some people hold negative perceptions of ethanol (e.g., ethanol damages engines).

The goal of this study is to determine how much survey participants are willing to pay for cellulosic wood ethanol. Cellulosic ethanol made from wood has the potential to reduce carbon dioxide emissions and reduce oil imports while also reducing current conflicts between food and fuel production associated with some sources (corn, sugarcane) of ethanol (Solomon et al., 2007; Solomon & Johnson, 2009). However, an important consideration for market penetration by any product is the willingness of consumers to accept and use this product. Collantes (2010) reminds us that a consumer's value proposition (his/her perceived motivations for purchasing a certain product) for new technologies is best assessed in relation to existing mainstream technologies rather than in isolation. Therefore, the need to understand consumers *a priori* attitudes and beliefs regarding both gasoline and biofuels is of particular importance. Since the environmental impacts of biofuels differ across source material, we must become familiar with whether consumers are aware of, or sensitive to, these differences (Wegener & Kelly 2008). There may also exist subsets within the consumer base whose existing characteristics, attitudes or beliefs would incline them towards purchase of environmentally preferred products, including fuels, if appropriate messaging information could be presented.

2. Literature review

Though some willingness-to-pay (WTP) studies have been performed recently (Collantes, 2010; Jensen et al., 2010), literature regarding the acceptance of cellulosic ethanol is generally limited due to the pre-market nature of the product (Solomon & Johnson, 2009); insights into the factors that may impact consumer selection and acceptance of environmentally preferred products can be garnered from the 'green' behavior literature (see Clark et al., 2003; Carrus et al., 2008; Ek, 2005).

Attitudes have often been found to be a precursor to environmental behavior (e.g., Birgelen et al., 2009; Fraj and Martinez, 2007; Kaiser et al., 1999; Chan 2001); although often the effect is relatively weak (Fraj & Martinez, 2007). Attitude¹ towards a behavior is defined by Ajzen as "the degree to which performance of the behavior is positively or negatively valued" (Ajzen, 2006). Fraj and Martinez (2007) report that environmental psychologists have indicated two sets of environmental attitudes: one based on the actual eco-behavior under study, the other being a more general eco-attitude (i.e., an attitude toward the environment, not at a particular behavior).

Norms are shared beliefs about how people should act (Schwartz & Howard, 1982); social norms are generally defined as what the individual perceives as expectations on their behavior held by social groups important to the individual (e.g. peers, family or colleagues). These social expectations are assumed to be supported by real or perceived sanctions so that the individual has an incentive to adhere to the social norms (Ajzen, 1988). Personal norms are internal expectations held by the individual; e.g., a sense of obligation (Schwartz, 1977).² These norms have also been found to positively influence a person's eco-related behaviors

¹In Ajzen's Theory of Planned Behavior model, attitudes are functions of beliefs.

²This is a common simple dichotomy; see Thøgersen (2006) for a rigorous taxonomy of norms.

(Ajzen et al., 2004; Ek & Söderholm, 2008; Hunecke et al., 2001; Thøgersen, 1999; Birgelen et al., 2009).

Perceived control reflects the degree to which a person views themselves as being able to perform a specific behavior. In other words, people exhibit a stronger willingness to change their environmental behavior when they feel they can individually have an effect on the quality of the environment (Roberts, 1996; Vermeir & Verbeke, 2006). Perceived behavioral control (Wall et al., 2008; Ajzen, 2002; Birgelen et al., 2009) is indicated to be a significant precursor to environmentally related behaviors, although sometimes there is no link found (Birgelen et al., 2009).

Willingness to pay (WTP) studies of biofuels to date have proffered mixed outlooks on the prospects of the market for biofuels in the U.S. Tatum (2010) found that the cross-price elasticity of gasoline and e85 derived from corn is near unity, indicating that the prices of corn ethanol and gasoline are closely linked, reducing its feasibility as a sustainable substitute. Evidence has also suggested that, given the high price, limited fueling availability, and reduced performance of cellulosic e85, owners of flex fuel vehicles have little incentive to discontinue using the current gasoline mix (Collantes, 2010). On a more optimistic note, Jensen et al. (2010) finds that average WTP estimates for cellulosic e85 range from 16.6 – 18.9 cents/gallon over e10 derived from corn, indicating an overall willingness to pay a premium for cellulosic ethanol.

3. Theory

Beginning with the economic assumption that demand is a function of price (P), other attributes of the product (A) and income (I) (Lancaster, 1971), we expand this theoretical model to include the decision maker's psychological characteristics (C). These characteristics include the standard theory of planned behavior variables: attitudes, beliefs, norms, and perceived behavioral control. The general theoretical model then becomes:

$$\text{Fuel choice} = f(P, A, I, C) \quad (1)$$

According to this model, choice (the decision to purchase fuel) is based on the attributes of the fuel (environmental, fuel security) and the individual's psychological characteristics - specifically their beliefs (perceptions) about the environment (e.g., the threat of global warming), fuel security (dependence on foreign sources of fuel), as well as attitudes towards new technologies and products.

Behavioral theories such as the cognitive hierarchy model and the theory of planned behavior suggest that attitudes are an important determinant of behavior. The cognitive hierarchy model, developed by Homer and Kahle (1988), asserts that people's behavior is the result of a cause-and-effect chain beginning with values, which shape beliefs, then attitudes and norms, and finally, determine the behavior itself. The theory of planned behavior has also serves as a common method for understanding the nature of the relationship between such beliefs and behavior. Daigle et al. (2002) studied environmental concern in the context of the theory of planned behavior, operating under the model that human behavior is guided by behavioral beliefs (attitudes towards a behavior), normative beliefs (beliefs about the normative expectations of others), and control beliefs (perceived ease or difficulty of performing the behavior).

4. Data and empirical model

4.1 Sampling and survey administration

During the summer of 2009 we administered a mail survey to a representative sample of 3,800 New England, USA residents³ (500 residents per state, with an over sample of Maine residents - 800). The sample frame was purchased from *InfoUSA*; the *InfoUSA* database contains information about 210 million US residents.

The survey was administered with multiple mailings, including an introductory letter sent by post return-receipt requested to identify undeliverable addresses. In total 382 Maine residents and 958 New England (non-Maine) residents responded to the survey for a response rate of 52 and 38 percent, respectively yielding an overall response rate of 40 percent. The overall response rate is marginal, suggesting that individual survey results may not be a valid representation of the knowledge, practices and attitudes of the New England adult population. However, our purpose here is not to extrapolate our survey results to the aggregate population but to examine differences in attitudes, beliefs and fuel choice behaviors across different types of people.

4.2 Survey design

The survey instrument was informed by focus groups held in Maine and Massachusetts during the summer and fall of 2008 (Teisl et al, 2009). The final survey instrument consists of six sections aimed at eliciting information regarding a consumer's environmental concern (in general, and regarding specific issues) including their experience with or knowledge of biofuels with a specific focus on cellulosic ethanol, consumer's driving habits, responses to environmental psychology constructs, a fuel choice experiment, current environmental behaviors and socio-economic characteristics.

The analysis of the fuel choice scenario is the basis of this chapter. Here, each respondent was asked to respond to one fuel choice scenario. In each scenario (Figure 1), respondents viewed information about three transportation fuels. One fuel represented their current fuel, one was a fuel that contained ethanol derived from wood and one fuel contained ethanol derived from corn. The fuels also differed in terms of price, environmental (greenhouse gases emissions) and level of fuel security (percent of fuel imported) attributes displayed. Respondents were told to assume that the products were exactly the same except for their prices and the information presented on the labels. Respondents were asked to assume they were purchasing one of these fuels in the near future (in a few months); this was to allow us to reasonably provide information about new fuels that were currently unavailable and allowed us to broaden the range of prices being used in the scenarios. Increasing the variation of the price variable in this way enabled us to better isolate its effect on the decision-making process. However, including prices significantly different than the actual market prices faced by the respondent may induce the respondent to reject the scenario altogether. Coupled with the fact that fuel prices vary significantly across the New England region, this problem is accounted for by the future frame of the question, making the choice seem reasonable.

The attributes displayed on the labels were chosen based on previous focus group research indicating that these attributes were the most important to consumers (Teisl et al. 2009). The

³The states included are Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island and Vermont.

actual values displayed on each label were generated from a normal distribution with predetermined means and standard deviations using Excel. Price per gallon for the consumer's usual fuel had a range of \$1.50 to \$4.50 with a mean of \$2.50, while price for wood or corn based ethanol ranged from \$1.30 to \$4.65 also with a mean of approximately \$2.50. The range of the greenhouse gases (GHG) levels presented to participants was based on carbon dioxide emission per gallon. Gasoline yields approximately 25 pounds of CO₂ per gallon.⁴ The range presented to participants was 15-25 pounds per gallon, with a mean of 20. Cellulosic ethanol yields 6.9 pounds per gallon to 12.5 pounds per gallon.⁵ Respondents were given information on the percent reduction in emissions (where 7.5 is a 65% reduction) with a range of 40 to 80 percent and a mean reduction of 60 percent (approximately 8 pounds per gallon).⁶ Information on corn-based ethanol's carbon dioxide emissions differ, however we based the scenario on an assumed 17 pounds per gallon (i.e. 20% reduction). Thus respondents were presented with a range of 5 to 60% reduction in GHG, with a mean of 23% reduction. Fuel import statistics for the scenario were based on Transportation Energy Data Book, Table 1.7 edition 27 (Davis et al., 2007). The price and attribute scores were then randomly assigned across respondents (i.e., each scenario is likely to have a unique price/attribute combination).

Although we provided price, environmental and fuel security attributes for each of the three fuels, we only provided information about ethanol and its source for two of the fuels. We did not provide this information for the respondent's current fuel because during the time of the survey administration, while all parts of the study area sold fuels containing ethanol, not all states where ethanol is sold required ethanol-containing fuels to be labeled on the fuel pump (Table 1). As a result, we included a question before the choice scenario explicitly asking the respondent if they currently use gasoline, gasoline mixed with 10 percent ethanol (e10), gasoline mixed with 85 percent ethanol (e85) or used diesel or other fuels. Surprisingly, 52 percent of the respondents claimed they were using gasoline without any ethanol even though e10 is the primary fuel sold in the region. Forty-five percent thought they were using e10 and the rest thought they were using e85, diesel or other fuels.⁷

That the sample of respondents was basically split in what fuel they thought they were currently using is problematic in that we need to define a status quo fuel to estimate a price premium for wood-based e10. To begin, we first used t-tests to examine whether the respondents who indicated they used only gasoline as their fuel (hereafter gas only respondents) were different than the e10 respondents.⁸ In general we find that the two groups differ significantly in a number of areas. Gas only respondents are more concerned about global warming, hold more positive views of ethanol, and have more positive

⁴Based on 98.2 kg CO₂e/mmBTU, U.S. Environmental Protection Agency, Regulatory Impact Analysis, Renewable Fuel Standard 2, p. 427.

⁵6.9 pounds per gallon is based on switchgrass at 27 kg CO₂e/mmBTU, 12.5 pounds per gallon is based on the "advanced biofuel" requirements of 50% decrease in GHG emissions compared to 2005 baseline gasoline at 98 kg/mmBTU (U.S. Fed Register/vol. 75, no 56./Friday, March 26, 1020/Table V.C-4).

⁶Our framing numbers on the GHG intensity of fuels differs from current values used by the US EPA. These reflect a change in evolving science of lifecycle GHG accounting of the various fuels. The range given to survey participants is within the range of currently accepted values.

⁷Given only three percent citing the use of e85, diesel or other fuel, we dropped these respondents from further analysis.

⁸Contact second author for full results.

Assume that **in a few months** you went to your usual station to buy some fuel. In addition to the fuel you usually buy, you find two other types of fuel. The only difference between the fuels is what appears below. Note we have given you some information about your usual fuel.

YOUR USUAL FUEL <u>\$1.52</u>	FUEL A <u>\$1.33</u>	FUEL B <u>\$1.44</u>
This product contains ethanol made from wood	This product contains ethanol made from wood	This product contains ethanol made from corn
Each gallon of this product produces <u>22</u> pounds of green house gases	Each gallon of this product produces <u>4</u> pounds of green house gases	Each gallon of this product produces <u>20</u> pounds of green house gases.
<u>63</u> percent of this fuel is imported	<u>50</u> percent of this fuel is imported	<u>57</u> percent of this fuel is imported

Which fuel would you purchase? (PLEASE CHECK ONE BOX)

- I WOULD CHOOSE MY USUAL FUEL
- I WOULD CHOOSE FUEL A
- I WOULD CHOOSE FUEL B

Fig. 1. Sample choice scenario; underlined numbers vary across respondents.

attitudes toward buying US-made products (Table 2). However, they are also less likely to try new products. In terms of their behaviors, gas only respondents drive less and use public transportation more often, but are less likely to belong to an environmental group or buy environmentally labeled products. *Importantly, they are twice as likely to choose the status quo fuel.* Given the above we determined that the model should allow for the status quo fuel to vary; in turn, the baseline fuel for gas only is modeled as not containing ethanol whereas the baseline fuel for e10 users is coded as containing corn-based ethanol. The choice to use corn-based e10 as the status quo fuel option is based upon our results that almost all respondents (97 percent) who have heard of ethanol as a fuel additive, cited corn is its primary source.

State	Labeling Required for Fuel Blends	Market Share 2009 of E10 (%)
Connecticut	Yes, at 1%	100
Maine	Yes, any blend	60
Massachusetts	Yes, at 1%	85
New Hampshire	No	85
New York	Yes, at 1%	90
Rhode Island	Yes, at 1%	95
Vermont	Yes, at 1.5%	65

Table 1. Northeast US E-10 Market Penetration and Labeling Requirements.

Sources: American Coalition for Ethanol, 2007 State by State Handbook; Fuel Testers

4.3 Estimated model

The goals of this study are to estimate respondents' willingness to pay a premium for wood-based ethanol and to determine the influence that different psychological factors may have on respondents' values for this fuel. Given the available data we operationalize the theoretical model (Equation 1) as:

$$\begin{aligned}
 C_{ik} = & \alpha_1 \text{PRICE}_{ik} + \alpha_2 \text{GHG}_{ik} + \alpha_3 (\text{GHG}_{ik} * \text{GWIMP}_i) + \alpha_4 \text{IMPORT}_{ik} \\
 & + \alpha_5 (\text{IMPORT}_{ik} * \text{USBUY}_i) + \alpha_6 (\text{IMPORT}_{ik} * \text{ECOBUY}_i) + \alpha_7 \text{WOOD_GAS}_{jk} \\
 & + \alpha_8 \text{CORN_GAS}_{jk} + \alpha_9 \text{WOOD_E10}_{jk} + \alpha_{10} \text{CORN_E10}_{jk} + \alpha_{11} (\text{WOOD} * \text{TEKNO}_i) \\
 & + \alpha_{12} (\text{CORN} * \text{TEKNO}_i) + \alpha_{13} (\text{WOOD} * \text{DAM}_i) + \alpha_{14} (\text{CORN} * \text{DAM}_i) + \varepsilon
 \end{aligned}
 \tag{2}$$

where C_{ik} is a dummy variable denoting individual i 's choice of the k th fuel; 1 denotes the fuel was chosen, 0 otherwise. PRICE is the fuel's price as given in the scenario. GHG denotes the pounds of greenhouse gases produced per gallon of fuel and IMPORT denotes the percent of the fuel that is imported. WOOD_GAS and CORN_GAS are binary variables denoting whether the fuel contains wood- or corn-based ethanol, respectively, when the status quo fuel is gas only. WOOD_E10 and CORN_E10 are binary variables denoting whether the fuel contains wood- or corn-based ethanol when the status quo fuel is corn-based e10. GWIMP, USBUY, ECOBUY, TEKNO and DAM are a set of psychological variables that were created through the use of factor analysis (explained below) which are meant to measure the individual's: concern about global warming; attitudes toward buying US-made and environmentally labeled products; aversion to trying new technologies or products; and perceptions of ethanol. These psychological variables are interacted with relevant product characteristics. ε is the error term. The model is estimated using conditional logit regression

4.3.1 Factor analysis

The survey contained a number of questions aimed at measuring individual's attitudes toward buying environmentally preferred products, US-made and new products, and their beliefs about ethanol. Two separate factor analyses were performed to confirm and develop these measures of attitudes and beliefs. All of the variables used to construct the factors (see Tables 3 and 4) used Likert rating scales (e.g. 1 = strongly disagree; 5 = strongly agree).

We use factor analysis on the above data to find a reduced set of factors that would help identify respondents by their psychological profile. Factor analysis is a data reduction technique used to investigate whether a group of variables have common underlying dimensions and can be considered to measure a common factor. Although the analysis can be used to summarize a larger number of variables into a smaller set of constructs; ultimately the analysis is not a hypothesis testing technique so it does not tell us what those constructs are (Hanley et al., 2005). In turn, the validity of naming the constructs is contingent upon researcher judgment and should be interpreted with some caution (Thompson & Daniel, 1996).

For the factor analysis we used principal components analysis followed by Varimax rotation. As is typical, factors with Eigen values less than one are dropped from further analysis as are variables with factor loadings of less than 0.6 as these are not considered statistically significant for interpretation purposes. To further verify the reliability of the factor analysis we compute Cronbach's alpha on the variables loading on each factor;

	'gasoline only'	'e10'
<i>Psychological variables</i>		
How concerned are you about the effect of global warming on the region	3.8	3.6
In general, I am hesitant to try new technologies	2.6	2.4
Reducing the amount I drive decreases global warming	3.8	3.6
It's worthwhile buying US-made products	4.3	4.2
<i>Perceptions of ethanol</i>		
Ethanol is cheaper than gas	2.8	2.5
Ethanol damages engines	2.8	3.2
Ethanol improves acceleration	2.7	2.5
Ethanol lowers fuel efficiency	2.9	3.2
Ethanol produces less pollution	3.5	3.2
Wood-based ethanol decreases dependence on foreign oil	4.2	4.0
Wood-based ethanol lowers the US trade deficit	3.8	3.6
Wood-based ethanol decreases global warming relative to gasoline	3.8	3.5
Wood-based ethanol decreases global warming relative to corn-based ethanol	3.5	3.3
<i>Behaviors</i>		
Miles of weekly driving	184	258
Percent belonging to an environmental group	21	27
Likelihood to buy eco-labeled products	2.9	3.1
Likelihood to use public transportation	1.7	1.5
Percent choosing the baseline fuel	20	10
<i>Demographics</i>		
Percent male	54	75
Age	55.5	55.5
Education (in years)	14.9	15.2
Average household income	80,700	91,000

Table 2. Sample of significant differences between the 'gasoline only' and 'e10' respondents.

aiming to have alphas greater than the minimum value of 0.70 suggested by Nunnally and Bernstein (1994).

The factor analysis on the first set of variables indicates that three factors (Table 3) explain respondent reactions toward buying environmental, new, and US-made products. Kaiser's overall measure of sampling adequacy is relatively high (0.85) indicating the factor model is appropriate; values greater than 0.80 are considered sufficiently high for analysis (SAS

	ECOBUY	TEKNO	USBUY
Buying greener products improves the environment	0.891	.	.
It's good to buy greener products	0.876	.	.
It's worthwhile to buy greener products	0.859	.	.
I improve the environment when I buy greener products	0.851	.	.
Reducing the amount I drive decreases global warming	0.736	.	.
I am hesitant to try new products	.	0.907	
In general, I am hesitant to try new technologies	.	0.886	
I am often skeptical about new products	.	0.860	
It's good to buy us-made products	.		0.867
It's worthwhile buying us-made products	.		0.876
Buying US-made fuel improves our economy	.		0.732

Note: Values less than 0.6 are not printed

Table 3. Factor analysis of individuals' attitudes toward buying environmental, new, and US-made products.

1994). We call Factor 1 ECOBUY because the variables loading highly on this factor reflect respondent's positive attitudes toward environmental purchasing. We call Factor 2 TEKNO as the variables loading highly on this factor mostly reflect people's hesitancy to try new products or technologies. We call Factor 3 USBUY because it reflects respondents' positive attitudes toward buying US-made products. Computation yields Cronbach's alphas of 0.91, 0.86 and 0.79, respectively; indicating our analyses have a relatively high degree of reliability.

Factor analysis on the second set of variables yields four factors (Table 4); here, Kaiser's overall measure of sampling adequacy is marginal (0.73). We call Factor 1 GWIMP as it relates to beliefs and concerns related to ethanol and global warming. The next three factors measure people's beliefs about the positive and negative aspects of ethanol or wood-based ethanol. Cronbach's alphas of 0.85, 0.52, 0.26 and 0.49, respectively; indicating only the first factor is relatively reliable. Given these result we drop Factors 2, 3 and 4 from further analysis.

Note that all factor loadings are positive (Tables 3 and 4) indicating that each of the factor scores are positively correlated to the variables originally used in their construction. In turn, although the factor scores are normalized to mean zero, the direction of each score is positively correlated to the direction of the original variables. Hence, higher (lower) factor scores indicate a higher (lower) level of importance for that factor.

We hypothesize that α_1 , the respondents' reaction to price, will be negative. We anticipate that α_2 and α_4 will also be negative as greenhouse gases and fuel imports should be negative attributes. The parameters on the three greenhouse gas and fuel import interaction terms, α_3 , α_5 and α_6 should also be negative as these parameters reflect the preferences of people who are more concerned about global warming, and have more positive attitudes toward buying US-made and environmentally preferred products. The signs of parameters on the

	GWIMP	Factor 2	Factor 3	Factor 4
Decreases global warming relative to gasoline	0.879	.	.	.
Decreases global warming relative to corn-based ethanol	0.868	.	.	.
How concerned are you about the effect of global warming on the region	0.828	.	.	.
Ethanol is cheaper than gas	.	0.742	.	.
Ethanol improves acceleration	.	0.715	.	.
Ethanol produces less pollution	.	0.650	.	.
Lowers the us trade deficit	.	.	0.877	.
Decreases dependence on foreign oil	.	.	0.819	.
Ethanol damages engines	.	.	.	0.813
Ethanol lowers fuel efficiency	.	.	.	0.802

Note: Values less than 0.6 are not printed

Table 4. Factor analysis of individuals' beliefs toward ethanol and wood-based ethanol.

four binary variables indicating the type of ethanol present in the fuel relative to the baseline fuel (α_7 , α_8 , α_9 and α_{10}) are indeterminate. The parameters on the four ethanol type interaction terms, α_{11} , α_{12} , α_{13} and α_{14} should all be negative as these parameters reflect the preferences of people who are hesitant to trying new products/technologies, or have more negative attitudes toward ethanol.

Note that the empirical model is consistent with our theoretical specification except we do not have good measures of norms and perceived control. In addition, we included several specifications of income in the model but income was never significant and so we decided to drop it from the final estimation.

4.3.2 Estimation of premiums

Estimates of the price premium garnered for wood-based ethanol are derived from the discrete choice model as follows and calculated as changes from the baseline:

$$\text{Premium} = (\mathbf{X}^* \boldsymbol{\alpha}^*) / \alpha_1 \quad (3)$$

where $\boldsymbol{\alpha}^*$ and \mathbf{X}^* denote the vector of parameter estimates and the vector of variables from (2) with the exception of the parameter estimate on price. Variables are coded such that product attributes reflect their average values. The psychological variables (GWIMP, USBUY, ECOBUY, TEKNO and DAM) are all coded to zero since factor scores representing the 'average' are already scaled to zero. The binary variables are coded to identify what ethanol is present in the chosen fuel relative to the baseline fuel. In turn, we will generate four premiums that reflect the combinations of e10 fuel (wood versus corn) and the type of respondent (those who think they currently buy e10 versus those who think they currently buy straight gasoline).

5. Results

As expected, the parameters on PRICE, GHG and IMPORT negatively impact purchase decisions. Also the parameter on the interaction term that measures how people's reactions to the greenhouse gas attribute changes with increased concern over global warming (GHG * GWIMP) is negative, indicating that global warming concerns increase the negative reaction to the greenhouse gas attribute. Surprisingly, the parameter on the interaction term that measures how people with more positive attitudes toward buying US-made products react to the fuel import attribute (IMPORT * USBUY) is insignificant; whereas the similar interaction that measures how people with more positive attitudes toward buying environmentally labeled products (IMPORT * ECOBUY) is negative.

The parameters on the four binary variables indicating how the 'average'⁹ person reacts to wood- and corn-based ethanol, indicates that people who think they currently buy e10 are more likely to buy fuel containing either wood- or corn-based ethanol; whereas people who think they currently do not buy e10 are more likely to continue to buy gasoline without ethanol. Individuals who are less (more) likely to try new technologies/products are less (more) likely to buy wood-based e10, but have no special reaction for or against corn-based ethanol. Individuals who hold less (more) positive beliefs toward ethanol are less (more) likely to buy fuels containing ethanol.

	Parameter estimate	Standard error
Price per gallon (PRICE)	-7.942***	0.78
Pounds of greenhouse gases per gallon (GHG)	-0.041***	0.02
GHG * GWIMP	-0.037***	0.00
Percent of fuel that is imported (IMPORT)	-0.036***	0.01
IMPORT * USBUY	-0.001	0.00
IMPORT * ECOBUY	-0.019***	0.00
Wood-based e10: Base fuel is gasoline (WOOD_GAS)	-0.849***	0.21
Corn-based e10: Base fuel is gasoline (CORN_GAS)	-0.768***	0.23
Wood-based e10: Base fuel is e10 (WOOD_E10)	1.324***	0.43
Corn-based e10: Base fuel is e10 (CORN_E10)	0.758*	0.43
Wood-based e10 (WOOD) * Person avoids buying new technologies/products (TEKNO)	-0.269***	0.11
Corn-based e10 (CORN) * TEKNO	-0.175	0.12
WOOD * Person perceives ethanol damages engines (DAM)	-0.241**	0.10
CORN * DAM	-0.287***	0.11

Note: * denotes significant at the 10 percent level; ** denotes significant at the 5 percent level and *** denotes significant at the 1 percent level

Table 5. Discrete choice modeling results

⁹Here average means the person is average in their level of rejecting/accepting new technologies/products, and average in their positive/negative perceptions of ethanol.

The model parameters with appropriate variable coding provide estimates of the price premiums for the two types of e10 (wood-based versus corn-based) by the type of respondent (those who think they currently buy e10 versus those that think they buy gasoline without ethanol). Respondents who currently see themselves as buying e10 are willing to pay more for wood-based ethanol but not for corn-based ethanol (Table 6). The lack of a premium for corn-based ethanol is because these individuals are assumed to currently buy corn-based ethanol. As such, there are no greenhouse gas or fuel import improvements over the base fuel; however, there are greenhouse gas benefits for using wood-based ethanol (valued at about ½ cent for a 7 pound/gallon improvement in greenhouse gases). The other 7.5 cents appears to be driven by other unidentified benefits to using wood-based ethanol. Although not directly tested here, most respondents (70 percent) rated ‘increases local employment’ as an important benefit of producing and using ethanol made from trees.

Respondents who currently perceive themselves as using gasoline without any ethanol are also willing to pay more for wood-based ethanol (albeit less than the respondents above) but not for corn-based ethanol. Although these respondents respond positively to the larger greenhouse gas and fuel import reductions available with either ethanol relative to gasoline, they generally reject ethanol. We are not clear why this group rejects ethanol since the estimates here control for their perceptions of ethanol and their stronger aversion of trying new technologies/products.

	Wood-based e10	Corn-based e10
Estimate for respondents thinking they buy e10	\$0.08	\$0.00
Estimate adjusted for non-response	\$0.03	\$0.00
Estimate for respondents thinking they do not buy e10	\$0.03	\$0.00
Estimate adjusted for non-response	\$0.01	\$0.00
Share-weighted average premiums		
Based on unadjusted estimates	\$0.06	\$0.00
Based on estimates adjusted for non-response	\$0.02	\$0.00

Table 6. Per gallon premiums for two types of e10, by type of respondent and by share-weighted average

The above estimates reflect the responses of those interested enough in the survey topic to return a completed survey, and; thus reflects an upper bound estimate for each type of respondent. Only 40 percent of the sample actually returned the survey; if we were to assume non-respondents would not be willing to pay any price premium for ethanol, then a more representative willingness to pay estimate for wood ethanol would be \$0.03/gallon premium for ethanol buyers and \$0.01/gallon premium for non-ethanol buyers.

To develop a population estimate we weight the two wood-based premiums by the percent of respondents who fall into the two respondent types (i.e., 53 percent are currently gas buyers; 47 percent are currently e10 buyers). This weighted average premium for wood-based ethanol would range from \$0.02-0.06 per gallon, with no premium for corn-based ethanol.

6. Discussion

We find a small but significant premium for wood-based ethanol in the New England market. However, these premiums would only exist in the market if the different fuels were labeled and consumers were educated about these differences (e.g. through marketing). One key result is that about half of the respondents in our sample do not think they currently buy e10 fuel even though e10's market penetration in the region was around 94-97 percent (the lower percent removes New Hampshire from the calculation as it did not require e10 labeling at the time of the survey).

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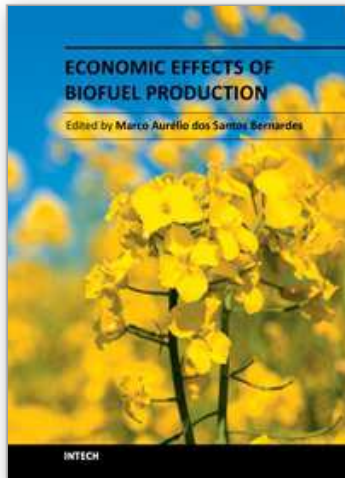
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This book aspires to be a comprehensive summary of current biofuels issues and thereby contribute to the understanding of this important topic. Readers will find themes including biofuels development efforts, their implications for the food industry, current and future biofuels crops, the successful Brazilian ethanol program, insights of the first, second, third and fourth biofuel generations, advanced biofuel production techniques, related waste treatment, emissions and environmental impacts, water consumption, produced allergens and toxins. Additionally, the biofuel policy discussion is expected to be continuing in the foreseeable future and the reading of the biofuels features dealt with in this book, are recommended for anyone interested in understanding this diverse and developing theme.

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