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Random preferences towards bioenergy environmental externalities: A case study of woody biomass based electricity in the Southern United States

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ABSTRACT

This paper contrasts alternate methodological approaches of investigating public preferences, the random parameter logit (RPL) where tastes and preferences of respondents are assumed to be heterogeneous and the conditional logit (CL) approach where tastes and preferences remain fixed for individuals. We conducted a choice experiment to assess preferences for woody biomass based electricity in Arkansas, Florida, and Virginia. Reduction of CO_2 emissions and improvement of forest habitat by decreasing risk of wildfires and pest outbreaks were presented to respondents as attributes of using green electricity. The results indicate that heterogeneous preferences might be a better fit for assessing preferences for green electricity. All levels of both attributes were positive contributors to welfare but they were no statistically significant. Respondents expressed a positive mean marginal willingness to pay (WTP) for each attribute level. The total WTP for green electricity per kilowatt hour was \$0.049 kWh or \$40.5 per capita year^{-1} when converted into future total annual expenditures.

1. Introduction

Forest biomass, a carbon neutral source of renewable energy (Gan, 2007), is one option for reducing the dependency on foreign energy and increasing the current share of the United States (U.S.) renewable electricity generation and renewable energy consumption by 9% and 7%, respectively (Energy Information Administration, 2009). As a result biomass based electricity production has received considerable public policy attention over the past few years. Many states have also adopted policies that promote green electricity—electricity generated from renewable resources—such as public benefit funds, renewable portfolio standard and green metering (Database of State Incentives for Renewable Energy (DSIRE), 2011b). Other policies such as feed in tariffs have also gained popularity, as evidenced by adoption by at least six states (Couture and Cory, 2009) and introduced as federal bill in the U.S. Congress (the Renewable Energy and Jobs Security Act, H.R. 6401) in 2008 (Farrell, 2009).

One of the most important policy instruments that promote biomass based electricity is the renewable portfolio standard (RPS) which requires that a certain percentage of the electricity generation must come from renewable energy sources (Aguilar and Saunders, 2010). As of May 2011, 29 states and the District of Columbia had adopted 43 RPS related to woody bioenergy (DSIRE, 2011b). Within the U.S. South, 6 woody biomass based RPS have been adopted by 5 states (DSIRE, 2011b). For example, Virginia enacted a voluntary renewable energy portfolio goal in 2007, which strived for a RPS goal of 4% of base year (2007) electricity sales in 2010 increasing up to 15% of base year electricity sales in 2025. In Florida, Jacksonville Energy Authority (JEA), a municipal utility, has committed towards generating at least 7.5% of its electricity capacity from biomass and other renewable sources.

Federal polices, such as the Healthy Forest Restoration Act of 2003 (United States House of Representatives, 2003) encouraged communities to utilize woody biomass through forest health projects as energy feedstocks. The Renewable Energy Production Incentive (REPI) and Production Electricity Tax Credit (PCT) created by the Energy Policy Act of 1992 (United States House of Representatives, 1992) set financial incentive payments for electricity generated by publicly owned utilities, and private investors and investor owned utilities, respectively, from qualified energy resources. The REPI provides 1.5

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cents per kilowatt hour incentive (in 1993 dollars, inflation adjusted) for biomass generated electricity for the first 10 years of operation. The PCT—updated by the 2009 federal American Recovery and Reinvestment Act, H.R. 1 (DSIRE, 2011a)—provides between 1.1 and 2.2 cents per kilowatt hour incentive for biomass based electricity production until 2013. The 2008 Farm Bill (United States House of Representatives, 2008) authorized mandatory funding of $1.1 billion for the period 2008–2012, providing grants and loans to promote cellulosic feedstock resources.

A number of studies have examined public preferences and willingness to pay (WTP) for green electricity in the U.S. (Farhar, 1999; Li et al., 2009; Roe et al., 2001). However, due to factors such as behavior and communication failures, the public's response green electricity seems to be latent, suggesting a need for additional demand analysis (Borchers et al., 2007). Most of the previous research has focused on the demand for renewable energy as a means of reducing of greenhouse gas (GHG) emissions. Scant research has focused on valuing the positive externalities associated with production of woody biomass based electricity, such as reduced risk of wildfire and pest outbreaks. The purpose of this paper is to explore public attitudes towards environmental and socioeconomic benefits associated with woody biomass based electricity production. We applied a choice experiment (CE) and used a random parameters logit (RPL) model to assess preferences and determine confidence intervals for the marginal willingness to pay (WTP) for positive externalities related to green electricity in the southern U.S. The RPL was compared against an alternative conditional logit (CL) approach to assess preferences. The CE asked respondents if they would participate in a green electricity program based on a green tariff mechanism (GTM) in which a fixed tariff per kilowatt hour of consumption is paid for green electricity.

The paper is divided into five parts. In Section 2 we outline the potential contribution of the U.S. forestlands to renewable energy and describe associated environmental benefits. In Section 3 we present the CE questionnaire and describe the attributes and socioeconomic variables. In Section 4 we outline the econometrics of the RPL model used for CE. In Section 5 we report the results and discussion. In Section 6 we summarize the main findings.

2. Forest biomass in the U.S. and environmental benefits

Forestlands in the U.S. can sustainably supply around of 368 million dry tons (MDT) of wood biomass annually for energy production out of which 36% is projected to come from logging residues and thinnings with large volumes from the South (Perlack et al., 2005). Other studies have estimated lower biomass production availability for bioenergy. For example, Milbrandt (2005) and Walsh (2008) estimated the U.S. yearly woody biomass potential to be 167 and 106 million dry tons, respectively. Hughes (2000) suggests that combining forest "energy" plantations in the future with the continued use of wood residues from forest product industries, forest biomass could supply 7–20% of U.S. electricity generation.

Silvicultural operations such as forestry thinnings can also improve forest sustainability by reducing the load of flammable material thus decreasing the risk of wildfires and pest outbreaks (Belanger et al., 1993; Neary and Zieroth, 2007; Speight, 1997; Susaeta et al., 2010). Wildfires increase soil erosion (Cochrane and Schulze, 1999; Dawson et al., 2001) and destroy wildlife habitats causing direct effects—death of organisms—and indirect effects—displacement of territorial birds and animals (Secretariat of the Convention on Biological Diversity, 2001). Pest outbreaks on the other hand can reduce nutrient cycling and carbon sequestration and damage wildlife habitat (Logan et al., 2003). For example, the southern pine beetle kills long leaf pines the nesting habitat of threatened species like red-cockaded woodpeckers (Coulson and Stephen, 2006). The removal of excessive forest biomass, thus, may enhance forest sustainability and reduce wildfire risk (Richardson, 2006). Forest bioenergy may also offer socioeconomic benefits such as increased financial returns to landowners and stimulating rural economies (Domac et al., 2005; Gan and Smith, 2007).

Cofiring and direct fired combustion are the commercially operated technologies that generate electricity from woody biomass (Bain and Overend, 2002; Guo et al., 2007). Cofiring is considered as the most cost efficient and effective option to reduce the net emissions of carbon dioxide (CO_2) from coal based electricity plants (Baxter, 2005; Nussbaumer, 2003; Sami et al., 2001; Tillman, 2000). Although Caputto and Hacker (2009) suggest that CO_2 emissions are reduced at the same linear rate as the fossil fuel that is offset, different rates of CO_2 mitigation have been estimated through life cycle analysis. For example, Robinson et al. (2003) and Southern Research Institute and the United States Environmental Protection Agency (2008) found a reduction of the CO_2 emissions of 10% for a cofiring rate of 20% and 15% on energy basis, respectively. The use of biomass for cofiring with coal has some inherent drawbacks such as high moisture content, low energy density, and low calorific value (Arias et al., 2008). Torrefaction of low quality biomass is a promising pretreatment technology to obtain uniform chemical and physical properties, and is also suitable for long distance transportation and long term storage (Phanphanich and Mani, 2011; Prins et al., 2006).

Lack of economic competitiveness—cost differential between biomass fuel and coal displaced by biomass fuel and increased capital cost to develop a cofiring plant—are considered as key factors responsible for the slow market development of biomass generated electric power (Hughes, 2000). Expanding existing power plants to cofiring plants and limitations imposed by current transportation systems might not support the generation of woody biomass based electricity at a wider scale (White, 2010). Furthermore, lack of people's interest and awareness on renewable energy issues can also act as an impediment to green electricity (Gan et al., 2007). Positive externalities associated with green power such as reduction of carbon emissions, increased energy prices, research and development of efficient production technologies, clear and consistent policy objectives and adequate policy instruments are critical factors towards overcoming these barriers and stimulating the production of biomass based power production (Gan and Smith, 2006; Gan et al., 2007; McCarl et al., 2000).

3. Choice experiment questionnaire

We employed an online survey based choice experiment (CE) to elicit the public's preferences for green electricity in Arkansas (AR), Florida (FL), and Virginia (VA). Online surveys can be implemented faster at lower cost while producing similar results to mail surveys (Flemming and Bowden, 2007; Marta-Pedroso et al., 2007). CE formats have been applied to a wider range of environmental management problems (Adamowicz et al., 1998; Boxall et al., 1996; Carlsson et al., 2007; Shrestha and Alavalapati, 2004). A main advantage of CE over contingent valuation method (CVM) is the ability to elicit marginal values of attributes of the good or service (Hanley et al., 2001).

The questionnaire consisted of two parts, the CE section and a section eliciting socioeconomic data. The first part of the CE section informed respondents about the benefits of producing woody biomass based electricity, i.e., reduced CO_2 emissions, reduced risk of wildfires and pest outbreaks. A "cheap talk script" was incorporated in the design to avoid hypothetical bias (Carlsson et al., 2005; Cummings and Taylor, 1999). The CE attributes and levels were based on a literature review of forest based bioenergy (Farnsworth et al., 2003; Gan, 2007; Polagye et al., 2007) discussions with academia, industry, and nongovernmental organizations' researchers in forest bioenergy, two focus groups of 12 people each, and a pilot survey. Descriptions and examples of the attributes and their levels were provided to respondents to facilitate comprehension. A brief description of the attributes and their levels is given in Table 1.

The levels of reduction of CO_2 and improvement of forest habitat by decreasing wildfires and pest outbreaks were obtained from existing literature (Agee et al., 2000; Fettig et al., 2006; Robinson et al., 2003; Southern Research Institute and United States Environmental Protection Agency, 2008; Susaeta et al., 2010). Since increased consumption of electricity varies seasonally, the timing of the survey could bias the respondent's responses. Furthermore, respondents might find it difficult to translate the impact of the premium of cents per kilowatt hour (kWh) to their total electric bill. We addressed these issues by providing respondents the average monthly consumption of electricity, price of electricity and monthly bill in 2007 for AR, FL and VA as a reference base (Energy Information Administration, 2010). This way, each premium level was linked to an average monthly payment.

Respondents were asked to choose between two alternative plans: Plan A in which respondents purchase green electricity and its associated reduction in CO_2 emissions and improvement in forest habitat conditions by reducing wildfires and pest outbreaks, and Plan B that reflects no change in current power consumption or environmental benefits. Although CE studies traditionally present two or more alternatives plus a status quo alternative (CM2), many researchers have begun to utilize one alternative plan and the status quo (CM1) in environmental studies (Adamowicz et al., 2007; Breffle and Rowe, 2002; Rolfe and Bennett, 2009). CM2 is often preferred due to its increased robustness and improved contrast (Rolfe and Bennett, 2009; Zhang and Adamowicz, forthcoming). Under the CM1 choice format respondents are more likely to choose the status quo option. On the other hand, cognitive burden on individuals may not necessarily increase when they face three or more alternatives (Caussade et al., 2005). In addition, strategic bias is less likely with the CM1 format (Carson and Groves, 2007). Since we are trying to mimic public choices for green energy in a referendum format, dichotomous choice modeling format is more realistic (Breffle and Rowe, 2002; Carson and Groves, 2007).

An example of the choice experiment is presented in Table 2. The choice question was presented as follows:

Are you willing to pay a monthly extra 1 cent per kilowatt hour for reducing the CO_2emissions between 1–5% (low reduction) and improving the forest habitat between 51–65% (high improvement) by reducing wildfires and pest outbreaks (Plan A) or not to pay a premium at all without having any changes in CO_2emissions and forest habitat improvement (Plan B)"

Table 1
Description of the attributes and levels.

Attribute	Description	Level
Redco	Percentage reduction of CO_2 emissions	1–5% (low) 6–10% (medium) 11–20% (high) 1–60% (low) 61–70% (medium) 71–90% (high)
Forhab	Percentage improvement of forest habitat[a] by reducing wildfire risk and improving forest health	1–20% (low) 21–50% (medium) 51–65% (high) 1–25% (low) 26–50% (medium) 51–75% (high)
Bid	Increase of the price the electricity per kilowatt hour in the monthly bill	\$0.01 \$0.02 \$0.03 \$0.04

[a] We broadly described forest habitat as species abundance, number of different species and health conditions of the forest. We followed this informal procedure to facilitate respondents' comprehension of this terminology and their choices about green energy.

Table 2
Example choice experiment.

Please choose	Plan A	Plan B
Redco	Reduction of CO_2 between 1 and 5% (low)	No reduction (0%)
Forhab	Improvement of forest habitat between 51 and 65% (high)	No improvement (0%)
Bid	Additional payment of 1 cent per kilowatt hour in your monthly bill	No extra payment (\$0)

In addition, respondents were presented with the following explanation of the impact of increases in the cost a kWh on their monthly electric bill:

"*You might not be familiar with an increase in cents per kilowatt hour and how it reflects in your monthly average bill. We will provide you some information to make your decision easier*"
"*In your state, the monthly average consumption is 1120 kilowatt hour and the cost of electricity is 11.8 cents per kilowatt hour. The average monthly bill is \$130. Below you will find the extra monthly payment you would have to make if the increase is:*

1 cent per kilowatt hour ≈ \$11 per month
2 cent per kilowatt hour ≈\$22 per month
3 cent per kilowatt hour ≈\$33 per month
4 cent per kilowatt hour ≈ \$44 per month

The number of alternative plans or choice sets were created using the SAS 9.1%MKTRuns and%MktEx macros (Kuhfeld, 2005). The three attributes and their respective levels provided 36 possible combinations ($3^2 \times 4^1$) for Plan A, achieving a 100% A-efficiency. We applied an orthogonal full factorial experiment design blocking the 36 combinations in 6 different versions, each containing 6 choice sets. Thus, each respondent received one questionnaire with six choice sets, each consisting of two plans, Plan A and Plan B, representing six different observations. Previous studies have demonstrated that six choice sets are sufficient to avoid violating the assumption of stability of preferences (Carlsson et al., 2003; Hanemann, 1984; Shrestha and Alavalapati, 2004). The socioeconomic variables from the second section of the CE questionnaire are described in Table 3.

Our web based survey was administered by Knowledge Networks (KN). KN has established since 1999 an online research panel (KnowledgePanel) that covers online and offline U.S. population, recruiting members based on probability sampling. Selected households were sampled through random digit dialing from KnowledgePanel with an equal probability design that is self weighting. Respondents were provided access to internet and hardware if needed and then email surveyed. Thus, representativeness of the sample was not limited to current internet users or computer owners. The sample survey weight was adjusted to U.S. Census geographic frame to correct error due to non-coverage of households that do not own telephone, oversampling of minorities or households with internet access, and subsampling of telephone households without an address. Non response bias was minimized during survey through efforts to increase participation and encouraged respondents to participate through incentives and newsletters. Monetary incentives of \$5 and \$10 were mailed to the respondents after completing the survey. KN included a toll free helpline providing assistance with survey questions to improve the respondent performance. In addition, non respondents were re-contacted frequently. The resulting data set was post-stratified using demographic distributions from the Current Population Survey (CPS) to reduce the effects of sampling and non sampling error in the outcome estimates (Huggins et al., 2002). A

Table 3
Socioeconomic variables.

Variable	Description
Knowledge	Knowledge of other natural resources based energy: 1 if respondent knows and 0 otherwise
Age	Years
Esaving	Ownership of energy saving devices: 1 if respondent owns saving energy devices and 0 otherwise
Education	High: 1 if respondent has a high school education or lower and 0 otherwise
	College: 1 if respondent had completed some college, 0 otherwise
	Bachelor: 1 if respondent has received a bachelor degree or higher level and 0 otherwise
Income	Lincome: 1 if household Annual Income is less than $24,9999 and 0 otherwise
	Mincome: 1 if household Annual Income is between $25,000 and $74,999 and 0 otherwise
	Hincome: 1 if Household Annual Income is greater than $75,000 and 0 otherwise
Location	Ark: 1 if respondent lives in Arkansas and 0 otherwise
	Flor: 1 if respondent lives in Florida and 0 otherwise
	Var: 1 if respondent lives in Virginia and 0 otherwise
Gender	1 if respondent is male and 0 otherwise

random sample of 280 households received the questionnaire in March and April 2008. A total of 204 questionnaires were returned in April of 2008. However, 22 surveys were not completely answered leaving 182 questionnaires available for analysis (46 in AR, 66 in FL and 70 in VA) (67% response rate) yielding 1092 data lines (6 choice sets × 182 questionnaires) for analysis.

4. Econometric model

The CE method is based on random utility theory in which the indirect utility of an individual is assumed to be the sum of a deterministic part and a stochastic element (Mcfadden, 1974). Formally:

$$U_{ijt} = \alpha_{ij} + \delta_j z_i + \beta_i x_{ijt} + \varepsilon_{ijt} \quad (1)$$

Where U_{ijt} is the utility for each respondent i to choose alternative j at choice situation t, α_{ij} represents the alternative specific constant or the inherent preference for the alternative, z_i and x_{ijt}represent the vector socioeconomic characteristics and attributes respectively, ε_{ijt} reflects unobservable influences on respondent choices, and δ_j and β_i are the coefficients of the utility function to be estimated. The individual chooses alternative j over alternative k from a choice set $C=\{C_{1,\ \ldots,}C_t\}$ if $U_{ijt}>U_{ikt}$, $j\neq k$; j, $k\in C$. If the disturbance term is assumed to be independent and identically distributed (IID) with a Type I extreme value distribution with a scale parameter μ (Mcfadden, 1974), the probability of choosing alternative j conditioned on β with scale parameter μ is:

$$P_i\left(_{jt}|\beta_i\right) = \exp\left(\mu\alpha_{ij} + \delta_j z_i + \beta_i x_{ijt}\right) \Big/ \sum \exp\left(\mu\alpha_{ik} + \delta_k z_i + \beta_i x_{ikt}\right) j, k\in C \quad (2)$$

Eq. (2) describes the standard conditional logit model (CL). However, CL is limited by its inability to include random variation in preferences. In other words, the CL coefficients are fixed for all respondents and the alternatives are independent implying the independence of irrelevant alternatives (IID) property due to the IID assumption (Train, 2003). An alternative approach to the conditional logit model (CL) is the random parameter logit (RPL). RPL is a flexible model that relaxes these two restrictions by allowing β_i to vary with density $f(\beta_i|\theta)$ where θ is a vector of the true parameter of the taste distribution. The unconditional probability of individual i for a sequence of choices is the integral of $P_i(_{jt}|\beta_i)$ over all possible values of β:

$$P_i(\theta) = \int \exp\left(\mu\alpha_{ij} + \delta_j z_i + \beta_i x_{ijt}\right) \Big/ \exp\left(\mu\alpha_{ik} + \delta_k z_i + \beta_i x_{ikt}\right)\ f(\beta_i\,|\,\theta) d\beta \quad (3)$$

Since the integral in Eq. (3) does not have a closed form, the probabilities have to be numerically approximated through simulation. We simulated the probabilities using Halton draws (Train, 2003). Eq. (3) allows the coefficients to vary among individuals but remain constant across the choices for each individual, reflecting stability of preferences for all individuals (Train, 2003). A word about the distribution of β is worth mentioning. As we expect that respondents have different preferences for the attributes of using green energy we assumed that the coefficients of the attributes except for the bid parameter were normally distributed, thus, allowing the sign of the coefficient to be positive or negative. As correlation is expected among the random coefficients the covariance matrix (Ω) of the normally distributed parameters was calculated; thus, $\beta_i \sim (\overline{\beta}, \Omega)$. Following Carlsson et al. (2003), the random coefficient was modeled as $\beta_i = \overline{\beta} + T\eta_i$ where T and η_i are the lower triangular Cholesky factor of the covariance matrix Ω ($\Omega = TT'$) and vector of independent random standard deviations, respectively. The bid parameter was assumed to be fixed and not normally distributed due to two reasons. First, we expected the marginal utility of income would be negative for all respondents; and second, the distribution of the willingness to pay has the same distribution as the distribution of the coefficient. We also only included one alternative specific constant (ASC) as our study was presented in a generic form.

One of the important features of CE is the ability to estimate the marginal rate of substitution between attributes (Carlsson et al., 2007). The mean marginal willingness to pay for a certain attribute equals the ratio between the attribute coefficient (α_j) and the marginal utility of income (β_j) (Hanemann, 1984). Formally:

$$\text{Mean Marginal WTP} = \alpha_j / \beta_j \quad (4)$$

However, this approximation only considers a discrete change in the level of the attributes and no information is provided regarding the confidence intervals of the random WTP (Risa Hole, 2007). Therefore, we applied the Krinsky–Robb method (Krinsky and Robb, 2005) to generate confidence intervals for the marginal WTP. A large random sample (n ≈ 5000) was drawn assuming a multivariate normal distribution with a mean and covariance matrix defined by the estimated coefficients from the choice model, simulating n values of WTP. The percentile method was used to determine the confidence interval of 90%, removing 5% of the simulated observations from each tail.

5. Results and discussion

Table 4 shows the summary socioeconomic statistics of the sample. The majority of the respondents were willing to pay a premium for green electricity. Those with a positive WTP were more likely to be middle income with higher levels of education and to have used energy saving devices.

NLOGIT 4.0 was used to estimate the RPL model using 250 Halton draws. Table 5 shows the coefficients, p values, and standard deviations of CL well as the random RPL model for woody biomass based electricity. The Wald chi square ($p<0.001$) suggested that both models were statistically significant, although the goodness of fit was low for each model (pseudo $R^2 = 0.076$ and $R^2 = 0.083$ for CL and RPL, respectively). The models were compared with the log likelihood ratio test under the null hypothesis that the log likelihood statistic for the RPL is no better than the log likelihood of the CL model. Although the

Table 4
Summary statistics for socioeconomic variables[b].

Variable	Mean
Knowledge	0.472
Esaving	0.764
Age	48.8
High	0.318
College	0.335
Bachelor	0.346
Gender	0.483
Head	0.868
Lincome	0.165
Mincome	0.533
Hincome	0.302
Ark	0.253
Flor	0.384
Var	0.362
Size	2.3
Work	0.588
Number of observations	1092

[b] Standard deviation for Age was 15.2 years and maximum and minimum values were 19 years and 81 years. Standard deviation for Size was 1.16 person and maximum and minimum values were 1 person and 5 people. All other variables took the value of 1 or 0.

log likelihood function did not increase substantially with the RPL model, the test rejected the null hypothesis at the 0.05 significance level. Furthermore, under the assumption that individuals have heterogeneous preferences in taste we concluded that RPL is the appropriate model for our analysis. Henceforth, our discussion will be based on the RPL specification unless otherwise noted.

In general, the coefficients of the CL and RPL and model do not have a straightforward interpretation (Bergmann et al., 2006; Greene, 2000). Thus we focus on their signs for statistical significant variables. As supported by previous studies on willingness to pay for renewable electricity (Hobky and Soderqvist, 2003; Roe et al., 2001), we expected that the environmental attributes such as reduction of CO_2 emissions (“Medium Reco” and “High Reco”) and improvement of forest habitat (“Medium Forhab” and “High Forhab”) to have a positive effect on the utility of the respondents. Although they showed a positive sign in the RPL model, none of the coefficients and standard deviations of the random attributes were statistically significant, in turn casting doubt regarding the heterogeneity of preferences for these attributes. The assumption of a normal distribution of the random attributes implies a probability that the coefficients may have opposite signs (Kataria, 2009). The probability of the inverse sign of each coefficient was calculated by using the mean coefficient and standard error of the distribution (Column 7, Table 5). The results indicated that there is a non negligible probability and respondents dislike all levels of reduction of CO_2 emissions and improvement of forest habitat. The correlation matrix showed a strong positive and negative correlation between “Medium Reco” and “High Forhab” and “Medium Forhab” and “High Reco”, respectively (Table 6). Low positive and negative correlations were found between “Medium Forhab” and “Medium Reco” and “High Reco” and “High Forhab”.

Table 6
Correlation and matrix for random parameters.

	β_1	β_2	β_3	β_4
β_1	1			
β_2	−0.254	1		
β_3	0.188	−0.997	1	
β_4	0.993	−0.356	0.294	1

The premium (“Bid”) was statistically significant and negative which means that the probability of paying a premium for woody biomass based electricity decreased as the premium increased and environmental benefits increased. The sign of “Bid” is also consistent with economic theory, i.e., as the price increases the demand for green electricity decreases.

5.1. Socioeconomic variables

The statistically significant likelihood of paying a premium for green electricity increased for respondents holding a bachelor degree (“Bachelor”) or higher as compared to respondents with only a high school education or less. Furthermore, the variable (“Bachelor”) was statistically significant.

We expected a positive income effect for green electricity with higher income respondents willing to pay higher for greener source of energy (Roe et al., 2001). Despite of the negative sign, neither High

Table 5
Conditional logit and random parameter logit estimations.

	Conditional logit		Random parameter logit				
	Coefficient	Std	Coefficient	Std	Coefficient Std deviation	Std	Probability reversed sign
Medium Reco β_1	0.133	0.160	0.260	0.468	3.003	2.341	0.456
High Reco β_2	0.188	0.167	0.263	0.367	2.264	2.243	0.460
Medium Forhab β_3	−0.028	0.157	0.034	0.365	2.305	1.807	0.462
High Forhab β_4	0.241	0.172	0.250	0.449	2.732	1.985	0.451
Bid	−22.712[e]	6.133	−34.072[e]	10.156			
Knowledge	0.338[d]	0.139	0.460[d]	0.213			
Esaving	0.230	0.153	0.304	0.224			
Age	−0.002	0.004	−0.006	0.006			
College	−0.302	0.164	0.076	0.227			
Bachelor	0.289[c]	0.177	0.528[d]	0.260			
Gender	−0.300[d]	0.131	−0.556[e]	0.207			
Mincome	−0.100	0.188	−0.186	0.262			
Hincome	0.143	0.213	−0.003	0.298			
Flor	−0.239	0.174	−0.249	0.244			
Var	−0.226	0.181	−0.179	0.245			
ASC	0.917[d]	0.437	1.585[e]	0.612			
No. of observations				2184			
Log likelihood	−699.05		−693.19				
Wald Chi square	115.74		127.45				
p value	0.00		0.00				
Pseudo R^2	0.076		0.084				

[c,d,e] Significance level at 0.1, 0.05 and 0.01, respectively.

("Hincome") nor medium income ("Mincome") were statistically significant. Similar findings were found by Bergmann et al. (2006). The dire economic conditions at the time of the survey might be attributed as the reason for these responses. Negative effect of higher incomes on the probability of paying a premium for green electricity have been explained by Hobky and Soderqvist (2003) who hypothesized that environmental concern might be considered a luxury good. Alternatively, if low income respondents expect to suffer disproportional damages from climate change, they may be more likely to pay more for green energy (Mendelsohn et al., 2006).

As expected individuals with knowledge ("Knowledge") of other sources of natural resource based energy were more likely to pay a premium for green electricity, this variable being statistically significant. The number of people in the household ("Size") and age of the respondents ("Age") were not statistically significant. Likewise, no significant differences were found between individuals residing in Virginia ("Var") and Arkansans ("Ark") compared to Floridians ("Flor"). Results also show that females were more likely to pay premium for green electricity, this variable ("Gender") being statistically significant. The effect of unobservable influences ingrained within the positive ASC was also statistically significant.

5.2. Willingness to pay (WTP)

Estimates of marginal and total WTP and total expenditures of using green energy are presented in Table 7 along with confidence intervals for the marginal WTP estimates. Although statistically insignificant, all mean marginal WTPs were positive indicating that respondents assigned positive values to the externalities generated by green electricity, although their confidence interval ranges from negative to positive values. However, all marginal WTPs were not statistically significant. Our welfare estimates ($0.001 to $0.008 kWh) were lower than the findings of Borchers et al. (2007), who estimated a marginal WTP of $0.013 kWh for generic unit of green energy. Based on the weighted monthly average consumption of electricity in AR, FL, and VA (Energy Information Administration, 2010) the marginal WTP for "Medium Reco" and "High Reco" averaged about $8.7 month^{-1}. These results compare quite well to Soliño (2010) who reported a mean marginal WTP of 77€ year^{-1} for reducing wildfires in Spain. The marginal WTP for "Medium Forhab" and "High Forhab" were $1.1 month^{-1} and $8.3 month^{-1}, respectively. We converted the total marginal WTP price premium for green electricity into future expenditures per month following the process followed by Solomon and Johnson (2009) and Susaeta et al. (2010). The total WTP was multiplied by the proportion of the total annual consumption of electricity (PE) given by the price elasticity of demand for electricity obtained from the model (EE). The total marginal WTP can be separated into an average price of electricity (PE) and the mean marginal WTP for electricity. Thus:

$$TE = (PE + WTP)PE*EE \tag{5}$$

We also generated confidence intervals for total expenditures following the same approach for marginal WTP. All marginal total expenditures were statistically significant at 0.01 level of significance. The total expenditures for medium and high reduction of CO_2 emission and high improvement of forest habitat conditions were around $29.4 per capita month^{-1} and $27.6 per capita month^{-1} for medium improvement of forest habitat conditions. CE can be used to determine the economic value different combinations of attributes and socioeconomic variables. The total mean WTP (consumer surplus) was calculated as:

$$\text{Mean Total WTP (consumer surplus)} = -\frac{1}{\beta}\left(V^1 - V^0\right) \tag{6}$$

Where V^1 and V^0represents the utility after and before the change, respectively. In our case, V^1 and V^0 stand for the indirect utility associated with choosing green energy and continuing using fossil fuel based electricity, respectively. The statistically significant total WTP, estimated with the Krinsky–Robb method, was $0.049 kWh ($55.6 month^{-1}) exceeded previous estimates in the literature. For example, Farhar (1999) estimated a monthly WTP of $5–$10 for the entire U.S. and Borchers et al. (2007) found a monthly WTP of $10.5 for 25% green electricity from biomass in the northern U.S. The total expenditures per person for choosing woody biomass based electricity were $40.5 month^{-1}.

6. Conclusions

This paper presented the findings of a choice experiment designed to elicit Southern U.S consumers' preferences for woody biomass based electricity. We compared results from applying the conditional logit (CL) model and a less restrictive specification allowing heterogeneous preferences for the attributes, the random parameters logit (RPL). Although the RPL specification performed better statistically better than the CL, the lack of significance and theoretically inconsistent signs of the coefficients and large standard errors of the attributes cast doubts on the superiority of the RPL.

Consumers in the southern U.S. expressed positive willingness to pay for environmental externalities generated from green electricity. The mean marginal WTP for all levels of reduction of CO_2 emission was around $0.008 kWh compared to $0.001 kWh for medium improvement of forest habitat conditions. Our findings also suggested that consumers would pay a premium for green electricity even in the absence of environmental benefits. Consistent with our expectations, people seemed amenable towards providing a premium for environmental benefits associated with green energy source such as the one produced by forest biomass. The total WTP accounted for 0.049 kWh reflected in total monthly expenditures of $40.5 per capita.

Our results should be useful for policy makers in formulating policy incentives for biomass production for green energy. For example, our results showing a positive WTP, support policies such as Jacksonville Energy Authority (JEA) municipal utility' Renewable Portfolio Standards of generating at least 7.5% of its electric capacity from clean and green energy sources by 2015 in Florida, and a RPS targeting a goal of 15% of the base year sales by 2025 in Virginia. The findings also highlight the need for engaging and educating consumers about the positive externalities associated with use of green electricity. Policy incentives focused on sustainable forest practices for biomass production can be a subject of further investigation. Further research is needed to disaggregate consumers'

Table 7
Marginal and total willingness to pay and total future expenditures, 90% confidence interval.

	Marginal WTP ($ kWh^{-1})	Total marginal expenditures ($ month^{-1})	Total WTP ($ kWh^{-1})	Total expenditures ($ month^{-1})
Medium reduction CO_2 emissions	0.0076 (−0.02, 0.035)	29.38 (21.96, 36.80)		
High reduction CO_2 emissions	0.0077 (−0.015, 0.031)	29.40 (23.14, 35.65)		
Medium improvement forest habitat conditions	0.001 (−0.024, 0.022)	27.60 (21.36, 33.83)		
High improvement forest habitat conditions	0.0073 (−0.02, 0.034)	29.30 (22.16, 36.44)		
			0.049 (0.032,0.065)	40.48 (35.93, 45.02)

preferences towards green sources of energy. Periodic revisions of these studies are required to ensure that policies that incentivize use of such energy sources reflect changing public attitudes and preferences. Our study covered three southern states. Potential variation of the welfare estimates in other regions of the U.S could also be explored.

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