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Hypothetical Market Familiarity and the Disconnect Between Stated and Observed Values for Green Energy*

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ABSTRACT: Participation rates and utility premiums for green power programs are generally less than implied by contingent valuation studies. This study compares open-ended and dichotomous-choice responses with actual participation rates of a green power program to examine the effect of hypothetical market familiarity. Traditionally, respondents are asked to value a renewable energy "block" which represents a quality improvement in a percentage of a good. When placed in a more familiar market setting, stated values are more closely aligned with premiums currently charged. Participation rates remain exaggerated indicating responses are viewed as a vote in favor of or against cleaner energy sources.

Keywords: Contingent valuation; green energy programs; renewable energy blocks; scope effects; coal-fired power plants; single-bounded dichotomous choice
JEL Classifications: H41; Q42; Q51

1. Introduction

Numerous studies have used nonmarket valuation techniques such as contingent valuation and conjoint analysis to value electricity from renewable resources (e.g., Wood et al., 1994; Farhar. 1999; Goett et al., 2000; Roe et al., 2001; Wiser, 2003; Zarnikau, 2003). These values in turn should represent actual payments and participation in green pricing programs. However, large discrepancies have been found between stated willingness to pay (WTP) for cleaner forms of energy production and actual payments and participation in existing green pricing programs. Residential participation in these programs, for example, ranged from under 0.1% to nearly 14% at the end of 2005 (Bird and Brown, 2006). With a median value of 1%, typical program response is well below the 30-80% of customers who express a willingness to pay for renewable energy in opinion surveys. In addition, while respondents have indicated an average WTP for cleaner air that ranged from $6 to $30, customers spent on average $5 a month to purchase or support green power through utility programs during 2002 (Bird et al., 2004).

Several explanations have been given for this lack of criterion validity including hypothetical bias (Champ and Bishop, 2001; Whitehead and Cherry, 2007) and bias due to elicitation format (Champ and Bishop, 2006). Kotchen and Moore (2007) find that program participation may be impacted by whether the program is based on a voluntary contribution mechanism or a green tariff mechanism. Borchers et al. (2007) suggest that a lack of information about the source of green energy (i.e., solar, wind, biomass) may impact program participation.

This study investigates the role of scope effects or part-whole bias (Mitchell and Carson, 1989). Based on actual green energy programs offered by utility companies, much of the previous economic research asks respondents to place a value on a renewable energy block consisting of a specified number of kilowatt hours per month corresponding to a percentage of the average household's utility bill (e.g., Champ and Bishop, 1998). This approach assumes the presence of scope effects in that people are willing to pay more to have all of their energy needs supplied by renewable energy compared to purchase decisions based on an energy block.

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However, lack of sensitivity to scope may be attributed to unfamiliarity with the hypothetical market setting. A renewable energy block represents an increase in quality of a percentage of a good. If valuing a good in a hypothetical setting is as difficult as previous research has shown, it stands to reason that valuing percent changes in the quality of that good should be even more problematic. As a result, lack of criterion validity in contingent valuation studies of green energy programs may be due to survey responses reflecting the more familiar setting where all of a household's energy needs are supplied by renewable energy.

This research utilizes results from an opinion survey designed to obtain Tennessee residents' opinions and attitudes on air quality in the state. In an attempt to place individuals in a more familiar market setting, this study was designed to ascertain values to have all of an individual's electric needs supplied by renewable energy. This alleviates information effects that could bias welfare estimates by allowing respondents to value renewable energy and not requiring them to understand a market situation they may not be familiar with. When placed in this more familiar market setting, open-ended WTP estimates for renewable energy are less than the cost of the same scenario in the actual market, thereby justifying the small participation rates observed in actual behavior. Results also indicate that dichotomous-choice responses for green energy programs are viewed more as a vote "in favor of" or "against" green energy and carry little ability to predict value. These results present an alternative explanation of the lack of criterion validity in green energy program studies.

2. Survey Design

The survey determined residents' opinions on various issues concerning air quality in Tennessee as well as personal demographics. The survey contained twelve questions concerning air quality, and six questions to obtain specific personal demographic information used in the regression analysis and to test for non-response bias. Overall results are calculated at a 95% confidence interval. The survey instrument is available from the author upon request.

Respondents were also posed a single-bounded dichotomous-choice contingent valuation question to determine the value of renewable energy production in the state of Tennessee. The payment mechanism was a premium added to their monthly electricity bills in order to have 100% of their power come from renewable resources. Seven bid amounts ($10, $15, $20, $25, $30, $40, $50) were randomly assigned to subsets of the survey sample. Bid amounts were based on previous literature on willingness to pay for green pricing programs as well as the actual cost of purchasing renewable energy from the local green energy providers (Wood et al., 1994; Farhar, 1999; Wiser, 2003).

Respondents were then asked to identify the maximum amount they would be willing to pay on their electric bill to have all of their electricity produced from renewable energy. This open-ended question was included based on previous green pricing program research that has found that while dichotomous-choice contingent valuation questions overestimate actual responses by approximately 30%, results from open-ended elicitation formats approximate actual responses (Ethier et al., 2000; Poe et al., 2002; Rose et al., 2002). Those that indicated they would be willing to pay nothing were then asked to indicate why in order to identify protest bids.

Survey data for the study was collected from randomly chosen households throughout the state of Tennessee. The random digit dial (RDD) survey was conducted via telephone from September 15 to September 24, 2003. The use of RDD survey methods reduces possible sampling error by including non-listed numbers. Respondents 18 years of age or older were randomly chosen from the household using the most recent birthday method. A total of 403 interviews were completed. The response rate was 15.6% using the American Association of Public Opinion Research's (AAPOR) standards for calculating response rates. Such a low response rate leads to concerns over non-response bias.

Non-response bias stems from over- or under-representation of certain segments of the population. In other words, the sample would differ from the population of the state of Tennessee. In order to alleviate the effects of non-response bias, data were weighted by age and gender to be representative of the population (Loomis, 1987; Dalecki et al., 1993). This approach computes a weighted average based on population proportions. The weights used to correct for differences between sample and population proportions are $W_i = N_i/S_i$ where N_i is the population proportion of the ith stratum of the critical variable in question, S_i is the sample proportion of the ith stratum, and W_i is the weight applied to observations occupying the ith stratum.

Missing observations for the open-ended and dichotomous choice WTP questions were omitted from the dataset. Sixty-five missing observations for other explanatory variables were replaced with the variable's sample mean. Replacing a missing observation with a sample mean is no different than eliminating that observation but still allows observations for other explanatory variables to be used. If missing values are systematically related to the explanatory variable, the sample mean may not be a representable estimate. "Don't know" responses to the open-ended question were omitted from the dataset. "Don't know" responses to the dichotomous choice WTP questions were replaced with "no" responses (Carson et al., 1998).

3. Contingent Valuation Methodology

3.1. Dichotomous Choice

The dichotomous choice procedure asks individuals to indicate whether or not they would be willing to pay a specified amount to have all of their power produced from renewable resources. Based on Cameron (1988), the willingness to pay function is modeled directly:

$$W(q^0, q^1, u^0, X) = e(q^0, u^0, X) - e(q^1, u^0, X) \quad (1)$$

where q^0 represents quality at the current level of nonrenewable energy consumption, q^1 represents quality at the reduced level of nonrenewable energy consumption, X is a vector of individual characteristics and utility is held constant at u^0. The individual will respond yes to the dichotomous choice question given a bid level of Z if

$$W(q^0, q^1, u^0, X) > Z \quad (2)$$

and will respond no otherwise. The probability of accepting the offer of reduced nonrenewable energy consumption (q^1) at the given bid level Z can be expressed as such

$$\Pr(Yes) = \Pr[W^*(q^0, q^1, u^0, X) - Z > \upsilon] \quad (3)$$

where W^* is the observable component of the bid function and υ is the unobservable random component of WTP. By varying bid amounts equally among individuals, a cumulative density function (CDF) of bid amounts can be estimated by specifying a functional form (Kanninen, 1995; Alberini, 1995).

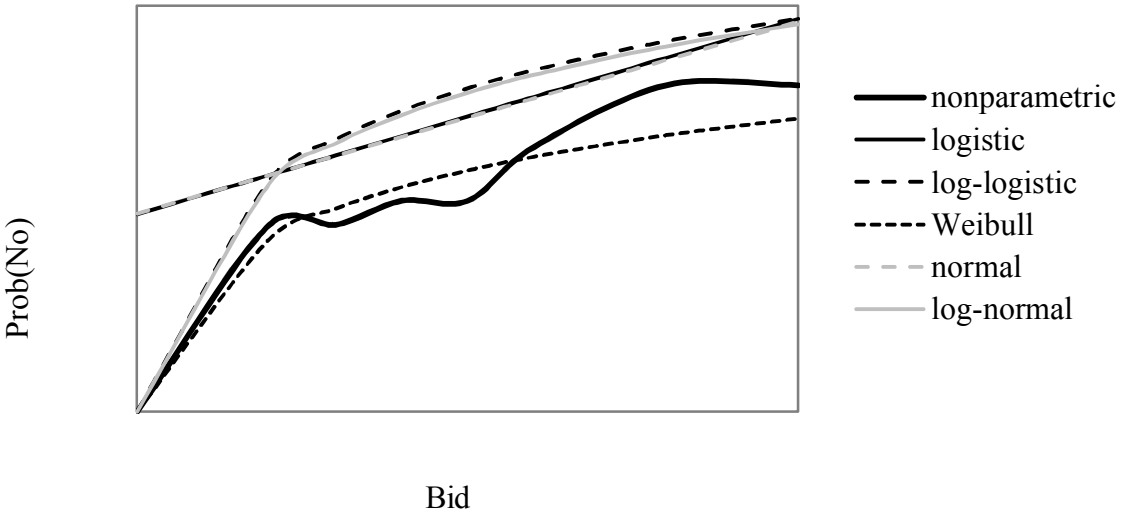
Common econometric problems such as omission of relevant explanatory variables and misspecification of the functional relationship between the dependent and explanatory variables can lead to erroneous policy conclusions. A number of demographic explanatory variables were included in model specification including age, education, gender, political affiliation, and the natural log of income. All but age and the natural log of income were found to be insignificant at the 5% level and were excluded from the final model. In addition to demographic information, a number of attitudinal variables concerning air pollution were also included in the regression model. In order to determine the effect of multicollinearity between explanatory variables, variance inflation factors were calculated for all explanatory variables included in the model. Because all variance inflation factors were found to be less than 2, it was concluded that the effects of multicollinearity do not bias estimated coefficients. Means, standard deviations, and definitions of variables can be seen in Table 1.

Table 1. Mean and Standard Deviation of Explanatory Variables

Variable	Definition	Mean	Standard Deviation
AUTO	Perceived impact of automobile emissions on air quality in the area (1=no impact, 5=great impact)	3.5028	1.1896
COAL	Perceived impact of coal-fired power plants on air quality in the area (1=no impact, 5=great impact)	2.4393	1.4594
GWARM	Perceived threat of global warming (1=not a threat, 4=high threat)	2.8980	0.8824
BID	Dichotomous-choice bid amount	27.8367	12.7466
AGE	Respondent's age	49.1079	17.0400
INC	Respondent's income on a 1 to 11 scale	6.4256	2.2268

In order to gain insight for the appropriate functional form, the nonparametric approach suggested by Kristöm (1990) was employed for the dichotomous-choice data. Such nonparametric approaches estimate dichotomous-choice data without specifying a functional form by assuming the distribution function is piece-wise linear between price points. These results provide valuable insight into the selection of a parametric distribution but are limited in their interpretation of the data. Likewise, various parametric approaches were also employed to estimate the dichotomous choice data and determine the most appropriate functional form. Comparison of the five parametric distributions and the nonparametric distribution can be seen in Figure 1.

Figure 1. Cumulative density function of a no response given a specific bid amount



The nonparametric welfare estimates suggest that the distribution of WTP is asymmetric (mean > median). Therefore, common distributions such as normal and logistic may not fit the data well. Welfare estimates based on the log-logistic and log-normal approach produced mean WTP estimates that were unrealistically large. The Weibull distribution was finally settled on because it is asymmetric and produced median WTP results similar to those of the nonparametric estimates. The probability of a yes response based on the Weibull distribution is

$$\Pr(yes) = e^{-e^{-\alpha-\beta*\ln(bid)-\beta*auto-\beta*coal-\beta*gwarm-\beta*age-\beta*\ln(income)}} \quad (4)$$

where α is the intercept and β is the coefficient on the covariates. The resulting likelihood function can be expressed as

$$\ln L = \sum_i Y_i \ln\left(e^{-e^{-\alpha-\beta*\ln(bid_i)-\beta*auto_i-\beta*coal_i-\beta*gwarm_i-\beta*age_i-\beta*\ln(income_i)}}\right) + \sum_i (1-Y_i)\ln\left(1-e^{-e^{-\alpha-\beta*\ln(bid_i)-\beta*auto_i-\beta*coal_i-\beta*gwarm_i-\beta*age_i-\beta*\ln(income_i)}}\right) \quad (5)$$

where $Y_i = 1$ if $WTP_i \geq bid_i$ (Poe and Vossler, 2002) and zero otherwise.

The Kolmogorov-Smirnov goodness of fit test (Smirnov Test) is often used to test for differences in underlying distributions and is a good procedure for testing the applicability of specific parametric distributions when a nonparametric distribution is known (Conover, 1980). The test is based on the Kolmogorov-Smirnov D-statistic

$$D_{K\text{-}S} = \max \left| N(x) - W(x) \right| \quad (6)$$

where $N(x)$ and $W(x)$ depict the nonparametric and Weibull distributions, respectively. In applying the Kolmogorov-Smirnov goodness of fit test to the two distributions, the approximation for the critical D value is 0.200. Based on these findings, the hypothesis of equal distributions cannot be rejected beyond the 5% significance level further supporting the use of a Weibull distribution.

Mean and median WTP estimates were calculated by integrating under the empirical CDF. Based on the Weibull distribution, mean and median WTP was calculated in the following manner

$$\text{Mean WTP} = e^{\alpha/\beta}\,\Gamma\{1-(1/\beta)\} \quad (7)$$

$$\text{Median WTP} = e^{\alpha/\beta}(\ln 2)^{-1/\beta} \quad (8)$$

Summing over all offered prices yields the estimate of mean WTP for the nonparametric specification

$$\text{Mean WTP} = \sum_i (b_{i+1} - b_i)\left(1 - \frac{F_i + F_{i+1}}{2}\right) \quad (9)$$

where b represents the bid level and F represents the probability of a no response. Median WTP for the nonparametric approach is found by solving the representative probability function for 0.5. Bounds on mean and median WTP estimates for the parametric specification were calculated using the Krinsky and Robb method (1986) with 1,000 random draws calculated at 95%. Confidence intervals for the nonparametric specification are calculated in the basic manner using standard errors (Vaughn and Rodriguez, 2001).

3.2. Open-ended

The open-ended question format simply asks the respondent for a maximum amount they would be willing to pay. Mean and median WTP is then calculated in the traditional manner. Previous research has shown that Tennessee residents do potentially hold negative WTP values for renewable energy (Jensen et al., 2003). However, the survey design only incorporates nonnegative WTP values thereby aggregating actual $0 WTP values with negative WTP values. In order to distinguish between limit ($0) observations and nonlimit (positive) observations, tobit censored regression was used to determine the relationship between open-ended responses and opinions on air pollution and global warming, age, education, and the bid value from the dichotomous choice question.

The bid value was included in order to identify possible anchoring effects that may arise by preceding the open-ended question with the dichotomous choice question. Basic socioeconomic and demographic variables were supplemented with attitudinal variables to gauge opinions on the relationship between coal fired power plants, automobile emissions, and air quality in the area. Previous research has shown that attitudinal variables often do a better job of predicting WTP response than do socioeconomic and demographic factors (Luzar and Cosse, 1998; Kotchen and Reiling, 2000).

Once again, multicollinearity was found to not be a concern as all variance inflation factors were less than 2. Likewise, heteroscedasticity was also tested for using a likelihood ratio test. Results suggest that the dichotomous choice bid exhibits heteroscedasticity. Therefore, an additional parameter corresponding to this heteroscedasticity was estimated using traditional maximum likelihood methods. The marginal effects in the heteroscedasticity model will generally be very similar to those computed from the model which assumes homoscedasticity (Greene, 2003).

The tobit model is almost always estimated linear in parameters and covariates (Haab and McConnell 2002). Therefore, the model is specified in the following manner:

$$MAX_i = \alpha + \beta_1 AUTO_i + \beta_2 COAL_i + \beta_3 GWARM_i + \beta_4 BID_i + \beta_5 AGE_i + \beta_6 INC_i + \varepsilon_i \quad (10)$$

where MAX_i is individual i's maximum WTP to have all power needs produced from renewable resources; $AUTO_i$ and $COAL_i$ are the respondent's opinion on the effect of automobile emissions and coal fired power plants on air quality in their area based on a 1(low impact) to 5(high impact) scale; $GWARM_i$ is the respondent's opinion on the threat of global warming based on a 1(not a threat) to 4 (high threat) scale; BID_i is the bid amount presented to the respondent in the dichotomous choice question; AGE_i is the respondent's age; INC_i is the respondent's income level; and ε_i is the corresponding normally distributed i.i.d. error term. If the underlying disturbances are not normally distributed, then the estimated coefficients will be inconsistent (Greene, 2003). Results from a Jarque-Bera test indicate that the null hypothesis of a normally distributed error term cannot be rejected. Means, standard deviations, and definitions of variables can be seen in Table I.

4. Results

4.1. Opinion Survey and Demographics

The purpose of this survey was to obtain opinions and attitudes regarding air quality in the state of Tennessee along with economic values and personal demographics. The survey produced an abundance of information that will only partially be covered in this text. The following is a summary of Tennessee residents' opinions on air quality issues facing the state of Tennessee as well as relevant demographic information. For a more complete coverage of basic survey results consult Fly et al. (2003).

The first two questions of the survey instrument were intended to gauge the respondents' personal opinions on air quality in their area. When asked to rate the level of air pollution in their area, only 16.1% indicated they felt that the air pollution in their area was high and only 8.4% felt it was very high. The largest percentage of respondents (35.6%) felt the level of air pollution in their area was moderate. Respondents were then asked to indicate possible sources of air pollution in the area. Mean responses indicate that respondents felt that automobile emissions had the greatest impact on air quality and coal-fired power plants had the least impact. Surprisingly, 38.4% felt that coal-fired power plants had no impact on air quality in the area.

Demographic results corresponded very well with Tennessee demographics with the exception of gender and age, which were weighted to be representative of the state population. Over 52% of the survey sample was female with an average age of 30 to 39 years old. Average household income for survey respondents was between $35,000 and $49,999.

4.2. Contingent Valuation

Binary choice regression was used to calculate the probability an individual would agree to pay $Z more per month for all of their electricity to be produced from renewable energy. As expected by theory, the natural log of the bid variable is negatively related to the probability of a yes response. Marginal effects reveal that a $10 increase in the bid amount results in a 12.9% decrease in the probability of a yes response. Age was also found to have a negative relationship to willingness to pay for renewable energy production. Model results also reveal that opinions on automobile emissions have an impact on willingness to pay for renewable energy production. Likewise, respondents were more likely to respond yes the greater their perception of the threat of global warming. Surprisingly, the relationship between opinions on coal-fired power plants and the probability of a yes response were insignificant. The natural log of the categorical income variable was also found to have a positive effect on the probability of a yes response for renewable energy as expected by consumer theory. These trends in age and income support results found in similar studies (e.g., Farhar, 1999; Wiser, 2003). Weibull regression results can be found in Table 2.

Table 2. Weibull Binary Choice Regression Results

Variable	Coefficient	Standard Error	Marginal Effects
Constant	0.6496	0.8116	0.1651
LNBID	-0.5085**	0.1776	-0.1292
AUTO	0.1728*	0.0774	0.0439
COAL	0.0810	0.0666	0.0206
GWARM	0.3330**	0.1003	0.0846
AGE	-0.0218**	0.0053	-0.0055
LNINC	0.5423**	0.1807	0.1378
Observations		349	
% Concordant		69.43%	
Chi-Square		60.07	
Log-Likelihood		-208.14	
McFadden's R^2		0.1261	
* significant at the 5% level of probability			
** significant at the 1% level of probability			

Nonparametric and Weibull based WTP estimates can be found in Table 3. Median WTP per month for renewable energy production in Tennessee calculated from Weibull results was measured at $45.10. This is much larger than the sample median WTP of $10 and even the mean WTP of $17.35. However, previous green pricing program research has consistently that dichotomous-choice contingent valuation questions overestimate actual responses by approximately 30% (Ethier et al., 2000; Poe et al., 2002; Rose et al., 2002). A measure of mean WTP is not possible because the coefficient on $\ln(BID_i)$ is less than 1 (Haab and McConnell, 2002).

Table 3. Willingness to Pay Estimates and Confidence Intervals*

	Nonparametric	Weibull	Tobit
Median	$34.10 ($26.74, $41.46)	$45.10 ($22.61, $67.58)	$19.90 ($12.35, $24.03)
Mean	$48.31 ($37.64, $60.12)	NA	$19.98 ($12.97, $23.81)
*confidence intervals calculated at 95% using Krinsky and Robb (1986) method			

The tobit model evaluated at the sample mean predicted a maximum WTP for renewable energy of $19.98 overestimating the sample average by a mere $2.63. Once again respondent's opinions on the impact of automobile emissions on air quality had a positive influence on stated WTP at a 5% significance level. Attitudes on global warming were also found to be significant in predicting stated WTP. As in the dichotomous choice model, WTP for renewable energy was found to be negatively influenced by age. For instance, a 10 year increase in age would result in a decrease of $1.89 in WTP based on marginal effects. Tobit WTP estimates and regression results can be found in Table 3 and Table 4 respectively.

Table 4. Tobit Censored Regression Results

Variable	Coefficient	Standard Error	Marginal Effects
Constant	3.0894	8.5402	2.0211
AUTO	2.1825*	1.2391	1.4278
COAL	0.7269	1.0620	0.4755
GWARM	3.8028*	1.6428	2.4878
BID	-0.1857	0.1452	-0.1215
AGE	-0.2891**	0.0910	-0.1891
INC	0.6075	0.6109	0.3975
Sigma	12.2597**	1.8298	
Heteroscedasticity Term			
BID	0.0210**	0.00571373	0.0002
Observations		261	
Log-Likelihood		-823.18	
LM Test		297.84	
ANOVA fit measure		0.0527	
* significant at the 5% level of probability			
** significant at the 1% level of probability			

When an open-ended contingent valuation question is preceded by a dichotomous choice contingent valuation question, the presence of anchoring bias becomes a concern. In order to identify possible anchoring bias in the open-ended results, the dichotomous choice bid amount was also included in the tobit specification. This variable was found to be insignificant at the 10% level, signifying the minimal nature of any anchoring bias in the results.

5. Discussion

The vast majority of Tennessee's population receives electricity from the Tennessee Valley Authority (TVA) and is eligible to participate in TVA's green pricing program known as the Green Power Switch. Through this program residents can chose to purchase blocks of renewable energy (roughly equal to 12% of a typical household's usage per month) through a $4 monthly premium added to the existing electric bill. Therefore, it would cost the typical Tennessee household approximately $33 to supplement all of their electric needs with green energy. Considering such low actual participation rates in TVA's Green Power Switch, a good measure of criterion validity in this case would be model estimates of WTP that are significantly less than $33.33. This is within the 95% confidence interval for median WTP obtained from dichotomous choice responses and is significantly more than the mean WTP estimates obtained from open-ended responses.

Another measure of criterion validity in the green pricing research has been the models ability to correctly predict actual participation rates in green energy pricing programs. Model results show little signs of improvement from previous research in this measure. TVA's Green Power Switch currently enjoys a 3% customer participation rate compared to a 25% response rate predicted by the dichotomous choice model evaluated at a bid amount of $33.33. While the model prediction of 25% is slightly less than the majority of participation rates predicted in previous research, it is still significantly larger than participation rates seen in actual behavior.

In response to these persistent discrepancies, it is important to identify remaining sources of bias with specific regard to any bias that may remain as a result of lack of knowledge with the good in question. The effect of this lack of knowledge can also be traced back to the problem of air pollution itself. For example, over 38% of those surveyed felt that coal-fired power plants have no effect on air pollution when in fact they are considered one of the main sources of pollutants such as sulfur dioxides and nitrogen oxides. This implies that some respondents are being asked to value a product (renewable energy) they do not believe will alleviate the problem of air pollution. Another source of bias may be related to familiarity or awareness of TVA's Green Power Switch. The lack of criterion validity found in previous studies assumes that the level of program awareness is held constant across the survey and actual participant samples. While participants are clearly aware of the program, survey participants may not realize that such a program is available to them. We feel this bias is minimal in this instance since TVA customers will be exposed to the Green Power Switch through inserts in their monthly bill and an active television advertising campaign.

6. Conclusions

Given the increasing the number of green energy programs in the U.S. (Bird and Brown, 2006), research that addresses the lack of criterion validity in contingent valuation studies of green energy program is warranted. Our results indicate that improvements in the predictive capability of stated responses resulting from the removal of confusing green pricing scenarios are inconclusive. Open-ended WTP estimates are robust in terms of criterion validity. However, dichotomous choice WTP estimates still appear to suffer from over inflation found in previous green energy valuation research. Furthermore, model results show no improvement in regards to the models ability to predict participation in green pricing programs.

This research does not apply a statistical scope test per se due to a lack of responses to different levels of green energy provision within this survey sample. A test for the presence of scope effects looks at whether respondents are willing to pay more for a good which is larger in scope (e.g. Brookshire, Ives et al., 1976; Hausman, 1993; Smith and Osborne, 1996). Regardless, these results indicate that the traditional assumption of the presence of scope effects in green energy pricing studies may be problematic. A more structured test for scope effects is left for future research.

These findings also appear to support the theory that dichotomous choice responses for green energy programs are simply viewed as a vote in favor of or against cleaner energy sources (Brown et al., 1996). If this is the case, no improvements in dichotomous choice responses would be expected as a result of the clarified market scenario suggested in this research. However, this clarification should increase respondent's ability to correctly place a value on renewable energy in an open-ended setting. In this regard, the clarified market scenario approach presented herein should be explored further.

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