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The W. A. Franke College of Business

Estimating Arizona Residents' Willingness to Pay to Invest in Research and Development in Solar Energy

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Julie Mueller
Assistant Professor

Northern Arizona University
The W. A. Franke College of Business
PO Box 15066

Flagstaff, AZ 86011.5066

Julie.Mueller@nau.edu

(928) 523-6612

Fax: (928) 523-7331

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Introduction

Arizona is the second-fastest growing state in the U.S., with the population increasing by an estimated 28.6% from April 1, 2000 to July 1, 2009.[1] Energy prices are volatile due to the current economic slowdown, and reliance on foreign oil remains troubling due to political instability in the Middle East. The idea that the United States needs to increase energy independence is relatively non-controversial, however, the ways in which energy independence can be achieved are highly debated issues. Increased investment into renewable resources such as solar, wind, biomass, and geothermal would increase energy independence without the negative environmental impacts associated with the use of non-renewable resources such as coal and natural gas. The state of Arizona has the highest potential for solar energy provision in the U.S. In fact, Arizona could meet 150% of the state's energy demand with solar energy. However, renewable sources of energy currently comprise less than 1% of the energy generated in Arizona.[2]

The composition of energy generated is going to change in the future, as Arizona is one of 26 states (plus Washington DC) to enact a Renewable Energy Standard. [3] The Renewable Energy Standard approved by the Arizona Corporations Commission states that by 2025, 15% of the energy generated in Arizona must be generated from renewable resources. Given the potential for solar energy in Arizona, current production of solar energy is surprisingly low. The lack of solar energy is attributable to the relatively high costs of producing solar energy, especially compared to non-renewable alternatives. For example, solar thermal electric is estimated to cost approximately $150 per Megawatt-hour (Mwh) while hydroelectric costs only $50/Mwh (Black and Veatch). Increased research and development into renewable technologies could lower the future costs to AZ energy customers. If AZ consumers are willing to pay to contributed to increased research and development into solar energy, it may increase the speed and efficiency with which AZ meets its mandated renewable portfolio goals.

Contingent valuation is a well-established survey method of eliciting values people place on goods, services, and environmental amenities not usually bought and sold in well-established markets. Since a blue ribbon panel of expert environmental economists was hired to determine the validity of contingent valuation to measure values from the 1990 Exxon Valdez oil spill, contingent valuation has been used to measure damages and benefits in environmental litigation and policies (Boyle 2004).

[1] http://quickfacts.census.gov/qfd/states/04000.html
[2] http://www.policyarchive.org/handle/10207/bitstreams/5146.pdf
[3] http://www.dsireusa.org/library/includes/tabsrch.cfm?state=AZ&type=RPS&back=regtab&Sector=S&CurrentPageID=7&EE=1&RE=1

Renewable energy provides the benefits of reduced pollution and increased energy independence, both of which are benefits not priced by traditional markets, and thus necessitating contingent valuation techniques to measure their value. Increased funding for research and development in solar energy may increase the speed with which new technologies are adapted and decrease costs of implementation.

Several studies have investigated willingness to pay (WTP) to obtain renewable energy using contingent valuation techniques. Two different studies by Champ and Bishop (2000 and 2001) found estimates for WTP for wind power for residents of Madison, Wisconsin. Their estimates ranged from $3.00-8.40 per month. Zarnaku (2003) found WTP for renewable energy for Texas residents to be approximately $7 per month. In a national study, Wiser (2007) found WTP for renewable energy to be approximately $8 per month. Thus, several previous studies provide evidence that residents of different regions in the U.S. are willing to pay to obtain renewable energy. In addition, studies have shown that WTP for renewable energy varies by age, education, and income (Zarnikau, 2003 and Batley, 2001).

Our study focuses on WTP for research and development in particular. In a national study, Li et al. (2009) found WTP for research and development into renewable technologies to be approximately $3.66 per month. To the author's knowledge, no contingent valuation studies of WTP for research and development have been conducted focusing on the Southwestern United States or Arizona in particular. While other studies provide the valuable insight that U.S. citizens are willing to pay more to see their energy provided by renewable sources, if Arizona residents have different preferences for renewable energy or solar energy in particular, the results from national studies may not be accurate measures of Arizona residents' WTP. Our study estimates what Arizona residents in particular are willing to pay to invest in renewable energy from the dominant resource in the state—solar energy. Estimation of WTP from survey data involves limited dependent variable techniques most commonly estimated using ML. Few studies have employed Bayesian estimation techniques despite their applicability with small samples (Albert and Chib 1993). Our study applies both traditional ML and Bayesian estimation to determine the mean and median WTP for solar energy in Arizona.

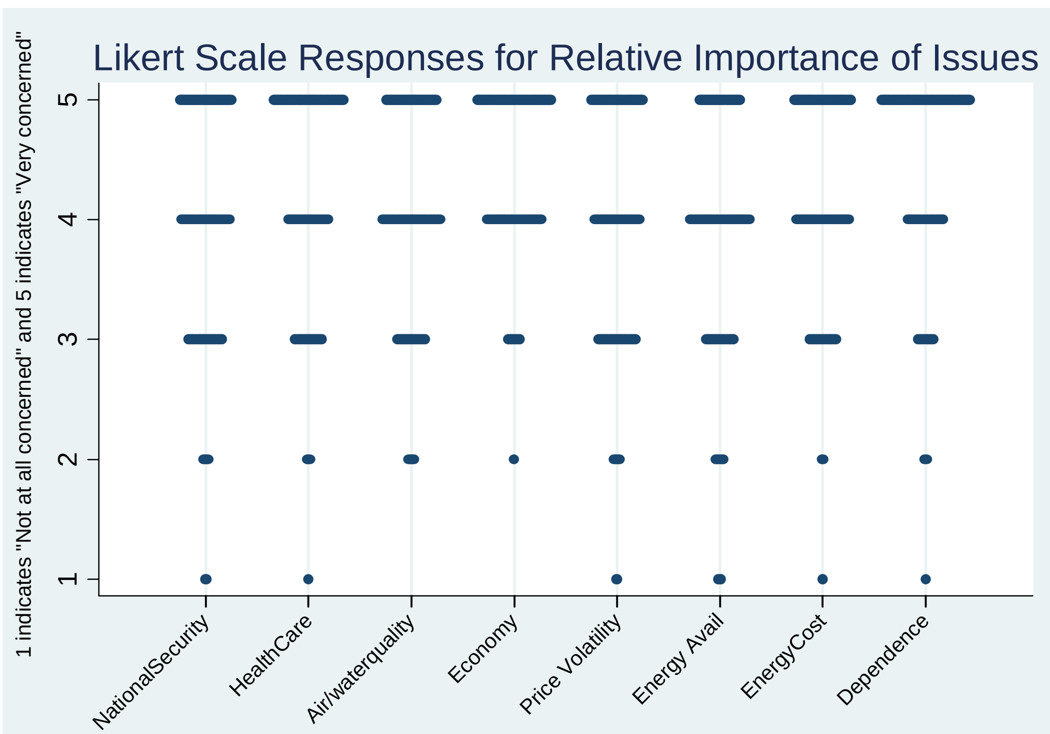
Data

Our data are obtained from a dichotomous-choice contingent valuation survey mailed to randomly chosen households in the state of Arizona. Addresses were obtained from Survey Sampling International. 600 surveys were mailed following the Tailored Survey Method by Dillman (2007). We sent an initial contact letter, followed by a survey booklet and cover letter with original signature. Shortly thereafter, we sent non-respondents a reminder postcard. We followed with a second cover letter and complete booklet mailing to the remaining non-respondents. We had a final response rate of 25.86% with 48 un-deliverables and 143 returned surveys. The survey is an 8 page booklet including the title pages and back cover. Pages 2-3 asked questions to determine respondents' opinions about energy and environmental issues relative to other issues facing Arizona. We also wanted to see if respondents were concerned about global climate change. Pages 4 and 5 of the survey present and ask the WTP question and then gather information about protest responses and respondent certainty. The 6th page asks several questions about respondent demographics, and the 7th page was blank with a request for comments.[4]

Respondent Opinions of Energy, Environment, and Pertinent Issues in Arizona

We first asked respondents to indicate their level of concern about pertinent issues in the state of Arizona on a scale of 1 to 5, with 1 meaning not at all concerned and 5 very concerned. Figure 1 shows Likert Scale frequencies for respondent answers to questions about issues in Arizona. Although respondents are generally concerned about all of the listed issues, reduction of U.S. dependence on foreign sources of energy generates the highest level of concern, with a mean on the Likert scale of 4.43 followed by the economy at 4.39. The relative strength of the importance of the reduction of dependence on foreign oil versus the economy is noteworthy in a state that has suffered deeply from the recession, with an unemployment rate of 9.6% in May of 2010, and foreclosure rates as high as 1 in 217 households in Yavapai County. [5, 6]

Figure 1: Relative Importance of Issues in Arizona



[4] The complete survey is available from the author upon request.
[5] http://www.bls.gov/lau/
[6] http://www.npr.org/templates/story/story.php?storyId=111494514

Next, respondents were asked about the importance to them of energy and environmental issues on a scale of 1 to 5 where 1 means not at all important and 5 means extremely important. The questions were phrased as follows, “Concerning the full range of issues we face today, how important are energy [environmental] issues to you?” The results shown in Figures 2 and 3 indicate that respondents are relatively more concerned about energy issues than the environment. We also wanted to obtain information about respondents’ confidence in adequate energy sources for the future. We asked them, “How confident are you that there will be adequate sources of energy to meet the needs of Arizona residents during the next 20 years? Please think about energy needs overall, including transportation, heating, electricity, and other energy requirements when considering your answer.” The mean response was 3.23, indicating that respondents are generally somewhat confident in adequate sources of energy in the future. The results are reported in Figure 4. Respondents were also asked, “On a scale of one to ten, where one means that nature is not easily damaged and five means nature is fragile and easily damaged, how do you view nature?” The results are reported in Figure 5. The mean response was 3.6, indicating that, on average, respondents view natures as somewhat fragile and easily damaged.

Figure 2: Importance of Energy

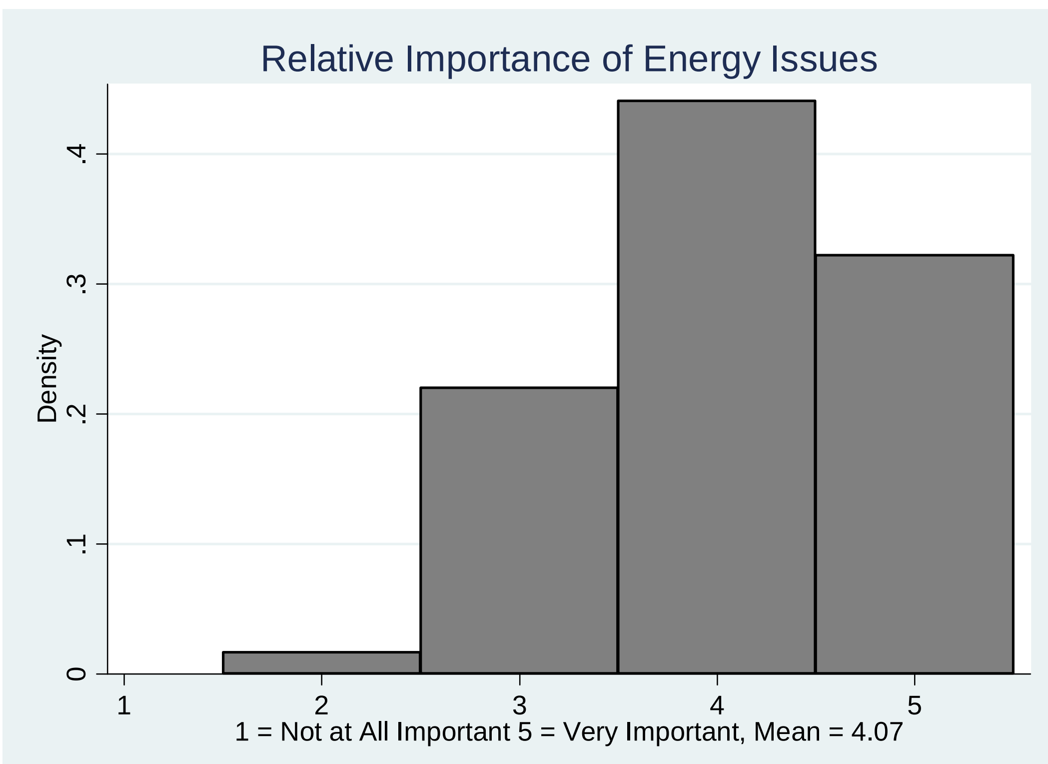


Figure 3: Importance of the Environment

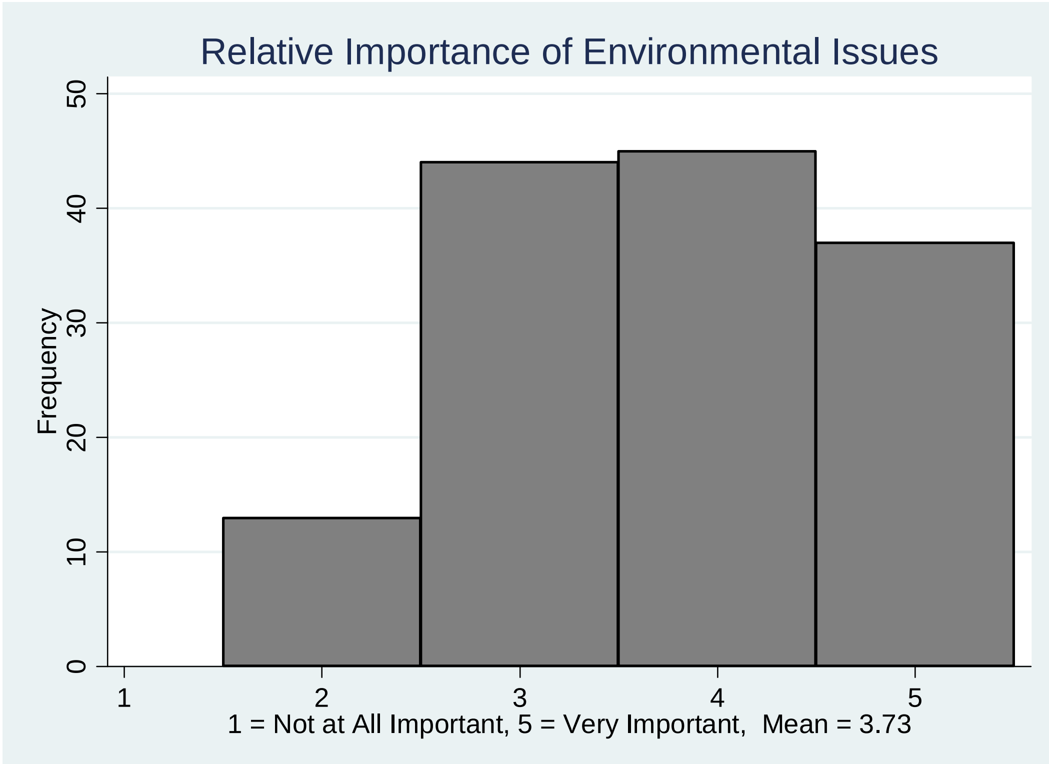


Figure 4: Confidence in Adequate Sources of Energy Response

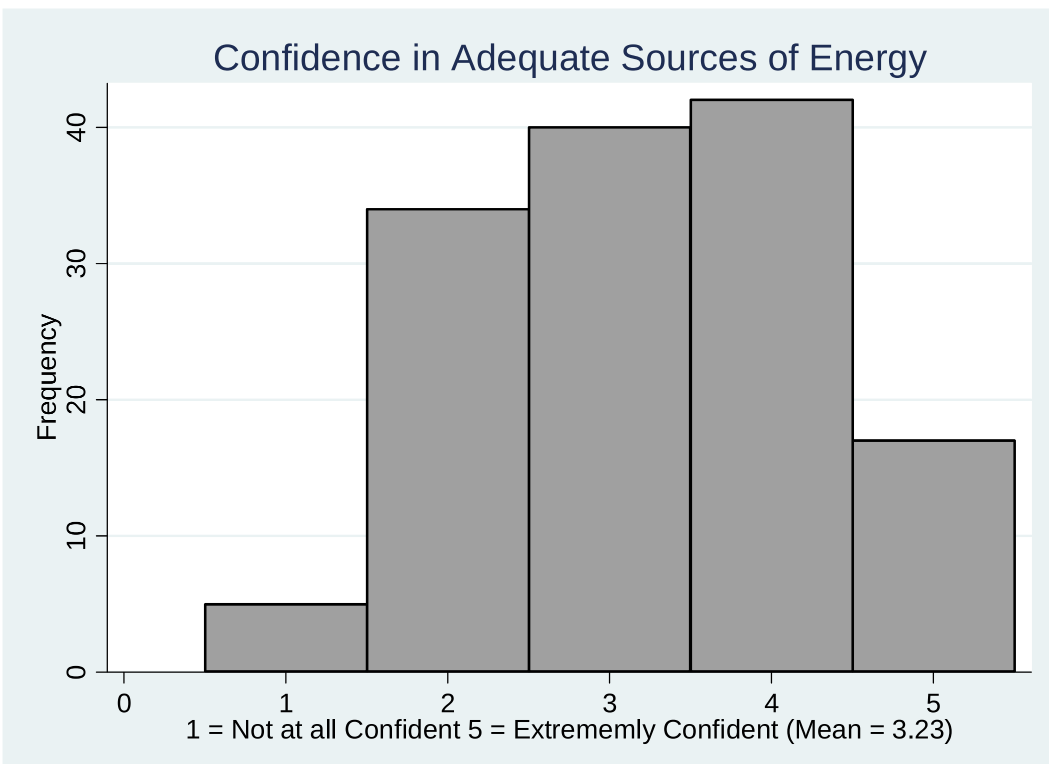
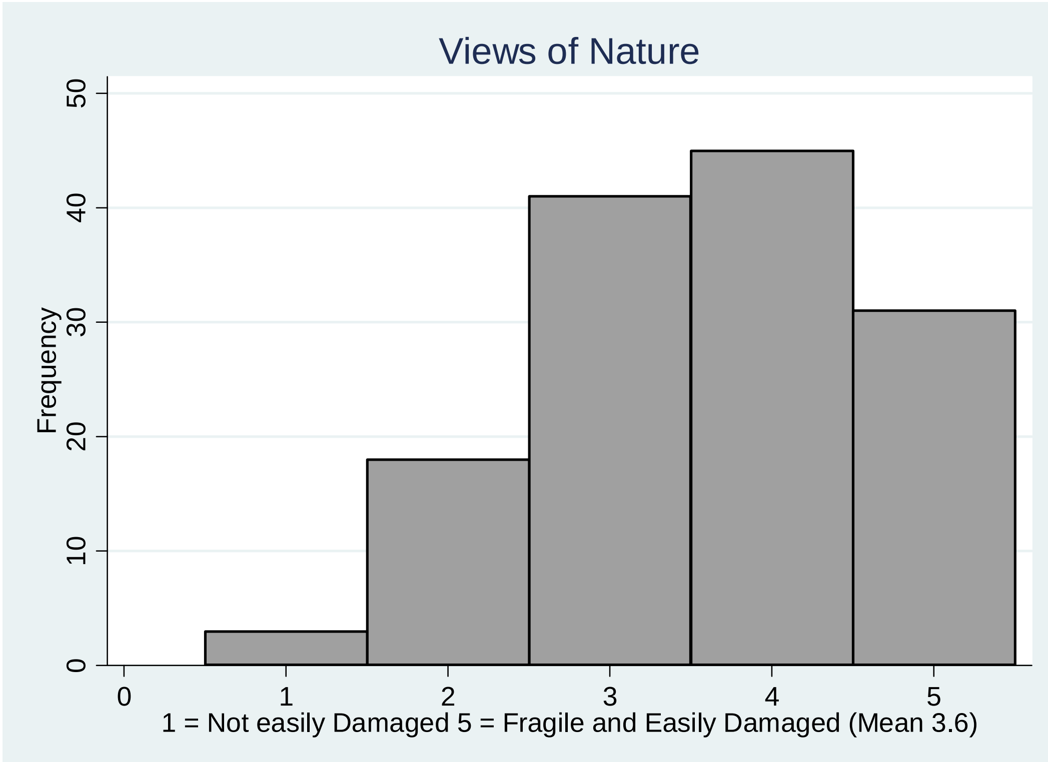


Figure 5: View of Nature

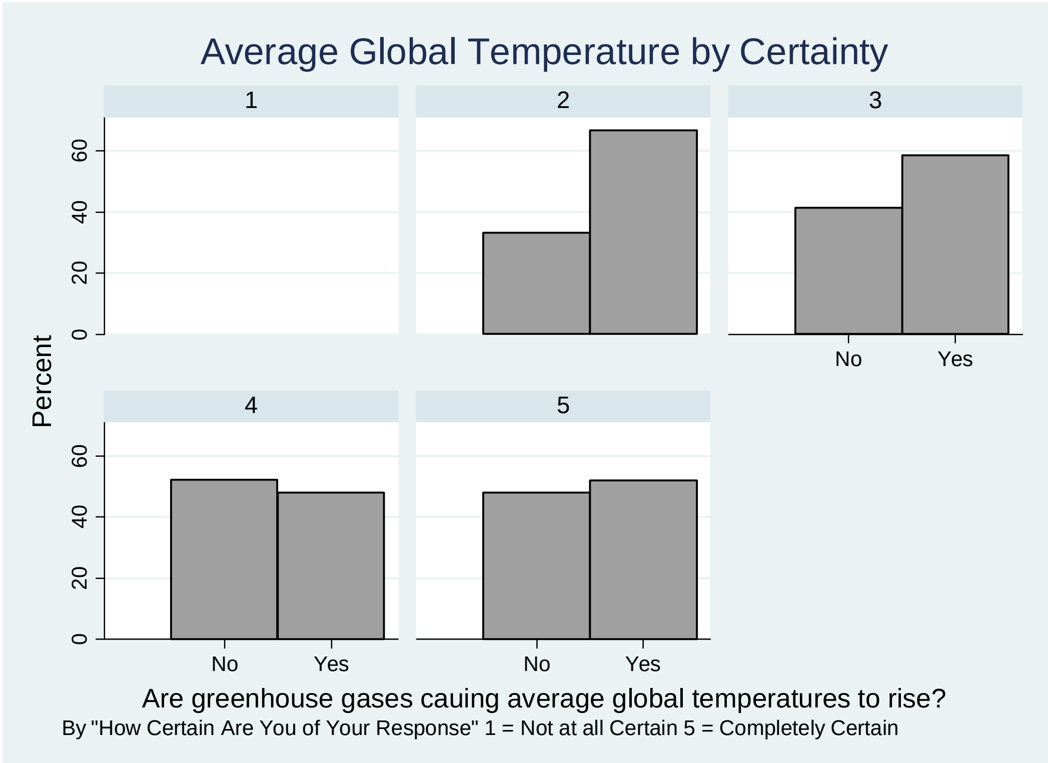


Arizona is a conservative state in the U.S., and opinions about global climate change are vastly different across regions. We asked respondents if, "In your view, are greenhouse gases, such as those resulting from the combustion of coal, oil, natural gas, and other materials causing average global temperatures to rise?" We then asked respondents on a scale of 1 to 5 how certain they were of their response, with 1 indicating not at all certain, and 5 indicating extremely certain. Figure 6 shows the answers to the greenhouse gases question sorted by certainty responses. It is noteworthy that most respondents were quite certain of their responses. Of the 133 respondents who answered the question, 52% answered "Yes." The average level of certainty is 4.02.

Willingness to Pay Question

Respondents were provided with a factual introduction to the issue of solar energy in Arizona. Respondents were then asked a WTP question based on a randomly assigned bid amount. The question is as follows, "If you were confident that all fees collected would directly be spent on increased research and development of specific solar technologies suited to Arizona, would you vote in favor of the referenda?" Bid amounts ranged from \$0.50 to \$200 per month. 150 people answered the WTP question. Respondents were also asked to rate their level of certainty on a scale of 1= not at all certain, 10 =

Figure 6: Answer to Global Temperature Question sorted by Certainty



completely certain. Of the 150 who responded to the WTP question, 66% voted "Yes." The average level of certainty was 8.18. Figure 7 shows the votes by bid amount. Notice that the percent voting "yes" generally decreases as the bid amount increases. Figure 8 shows the votes by certainty. The data indicate that some respondents were not very certain of their answer to the WTP question. How we address this uncertainty in our statistical methodology is described below.

To determine the general attitude of respondents to a possible referendum, we asked "How certain are you that the Arizona government would give the results of an advisory vote or referendum serious consideration in deciding whether to create a Solar Energy research and Development fund?" The mean value was 2.5, indicating that the average respondent was neutral. Figure 9 shows the distribution of responses to the government certainty question. We also asked respondents how they felt about holding a statewide advisory vote or referendum. Figure 10 shows the distribution of responses. The mean was 3.71, indicating that respondents are generally in support of a statewide advisory vote or referendum. Therefore, we find that most respondents are not certain that the Arizona government would give referendum results a strong consideration when deciding whether to create a Solar Energy Research and Development Fund, however, most respondents are in favor of holding such a referendum.

Figure 7: WTP By Bid Amount

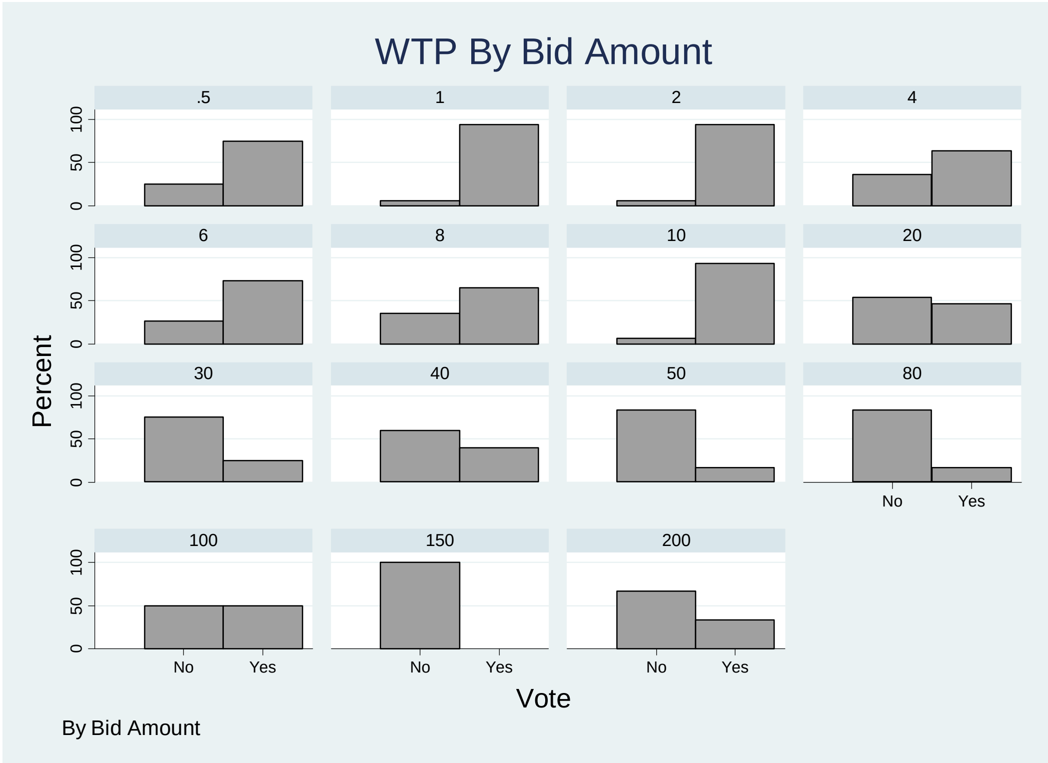


Figure 8: WTP by Certainty

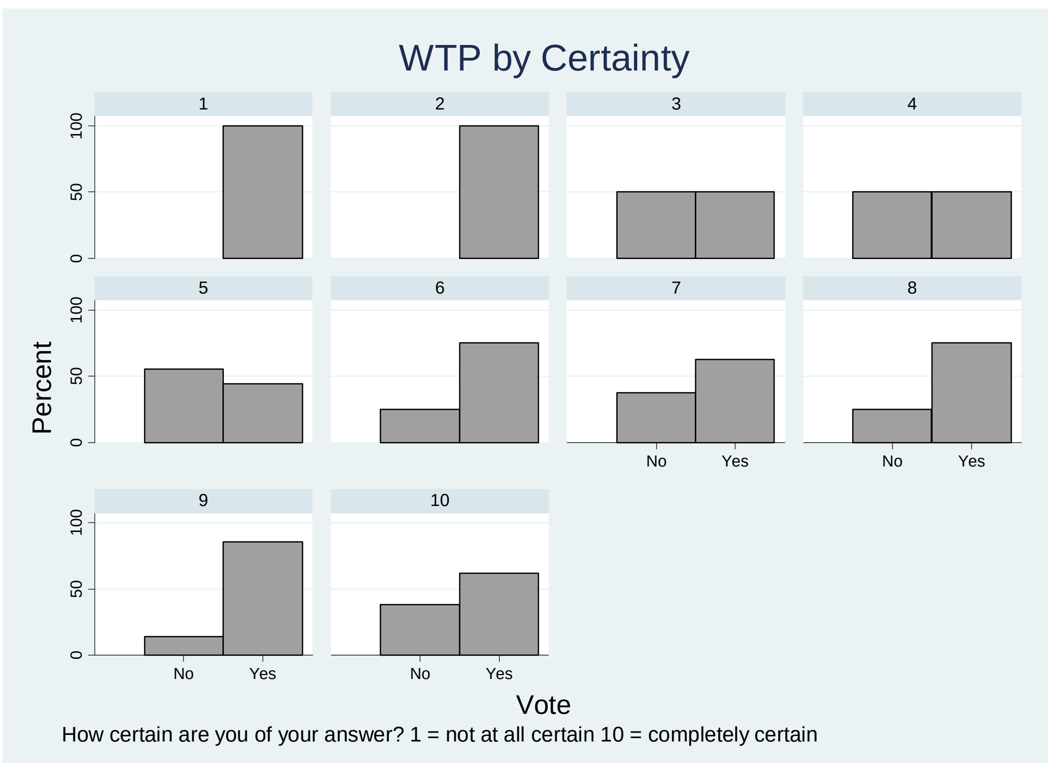


Figure 9: Certainty of Government Consideration

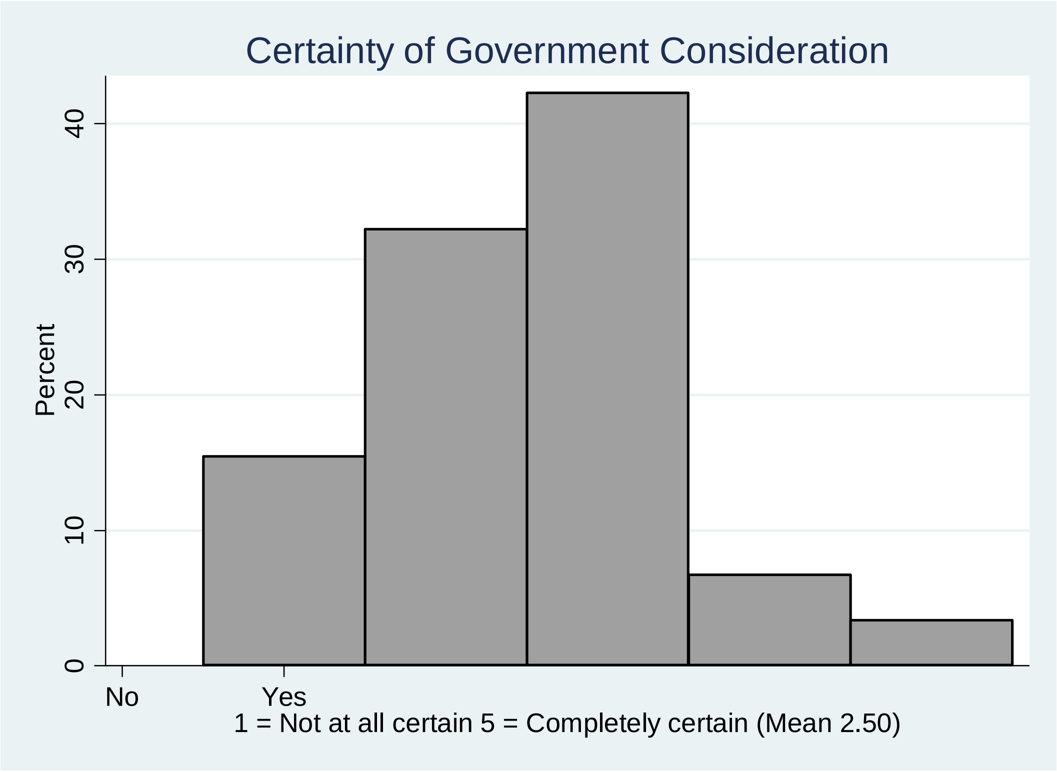
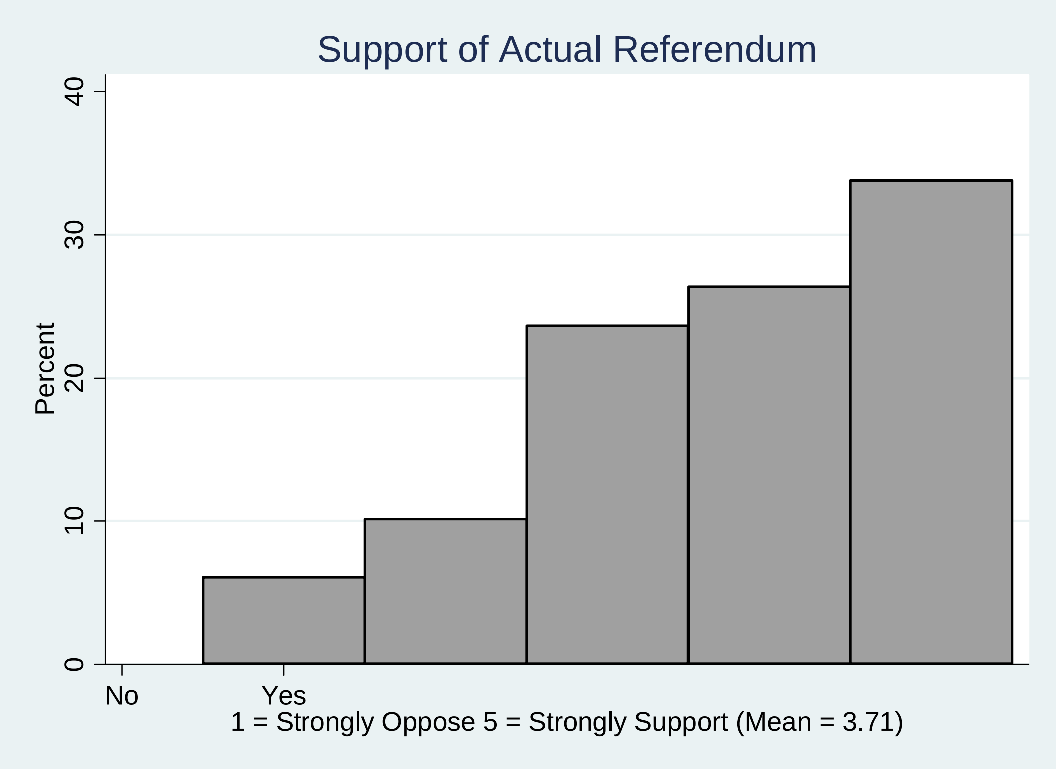


Figure 10: Support of Referendum



Respondent Demographics

Thirty-nine percent of our respondents were female, with the average age of 61. The majority of respondents are Republican, and the average income fell into the category of $60,000-$69,999. Figures 11-13 show the distribution of respondents' demographic characteristics. The average number of years of education is 15.5.

Figure 11: Race

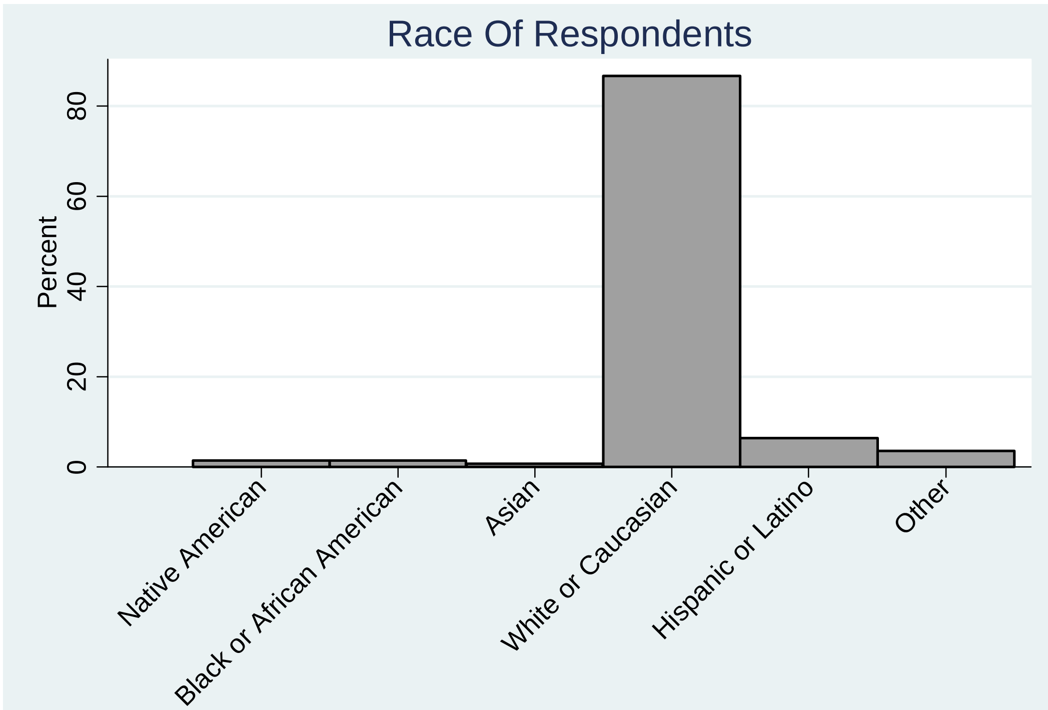


Figure 12: Household Income Before Taxes

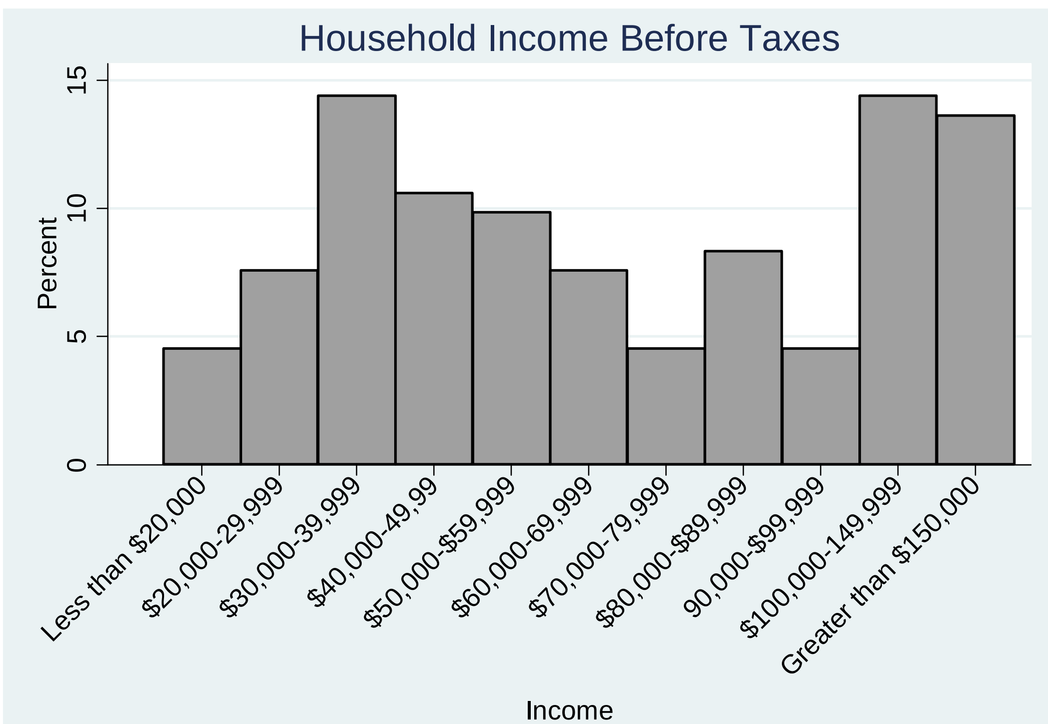
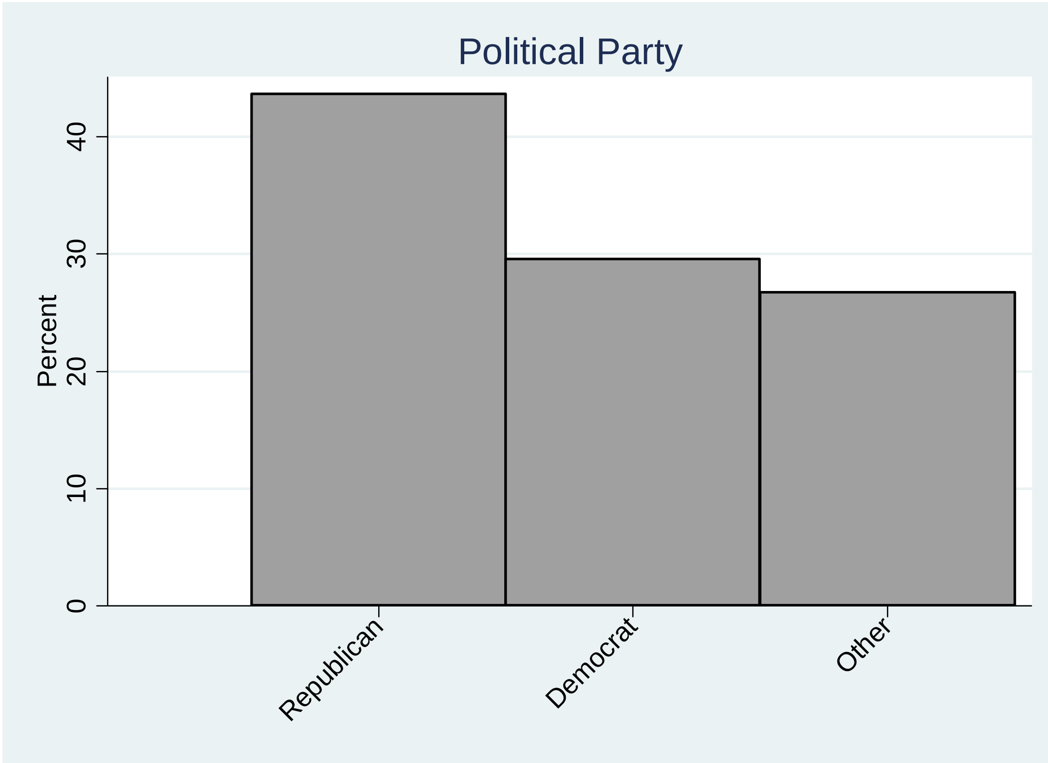


Figure 13: Political Party of Respondents



Methods of Estimation

We estimate the WTP function with a standard probit model using Maximum Likelihood and Bayesian techniques. Following Cameron and James (1987) The standard probit model is based on the assumption of an underlying WTP function

(1)

$$WTP_i = x_i'\beta + \mu_i$$

where x_i is a vector of explanatory variables, β is a vector of estimated coefficients, σ is a variance parameter, and μ_i is a random error term. The WTP function is not observable to the researcher, yet latent WTP is represented by the respondents' "vote" on the WTP question. Let y_i represent the respondent's vote, =1 if "yes" and 0 if "no." Assume μ_i are independent and normally distributed with a mean 0 and standard deviation σ, and Bid_i is the randomly assigned bid amount for each respondent *i*. The probability of a "yes" vote given the explanatory variables and random error is equal to the probability that the individual's unobserved WTP is greater than the bid amount. Therefore,

(2)

$$\Pr(y_i = 1|x_i) = \Pr(\mathrm{WTP_i} > \mathrm{Bid_i})$$
$$= \Pr(x_i'\beta + \mu_i > \mathrm{Bid_i})$$
$$= \Pr(\mu_i > \mathrm{Bid_i} - x_i'\beta)$$
$$= \Pr(z_i > (\mathrm{Bid_i} - x_i'\beta)/\sigma)$$

where z_i is the standard normal random variable. The standard probit model with *n* observations thus has the likelihood function:

(3)

$$logL = \sum_{i=1}^{n} \left\{ \mathrm{WTP_i} \log\left[1 - \Phi\left(\frac{\mathrm{Bid_i} - x_i'\beta}{\sigma}\right)\right] + (1 - \mathrm{WTP})_i \log\left[\Phi\left(\frac{\mathrm{Bid_i} - x_i'\beta}{\sigma}\right)\right]\right\}.$$

We estimate this likelihood function using Maximum Likelihood estimation. The WTP function is then obtained from the estimated coefficients using the Krinsy-Robb (1986) procedure.

Maximum likelihood estimation relies on asymptotic theory which may not be applicable with small or finite samples (Albert and Chib, 1993). Therefore, we also estimate the probit model using Bayesian estimation and Gibbs sampling (Gelfland et al 1990). Following Li et al. (2009), let WTP represent a latent variable on *n* observations. WTP for an individual is then a function of the explanatory variables, x_i, and the other parameters of interest β and σ. B_0 and s_0 are the initial values of the parameters of interest, N denotes the normal distribution and IG denotes the inverse gamma distribution. Thus,

(4)

$$WTP_i \sim N(X_i'\beta, \sigma^2)$$

and β and σ are independent with

(5)

$$\beta|\sigma^2 \sim N(\beta_0, \sigma^2 B_0^{-1})$$

(6)

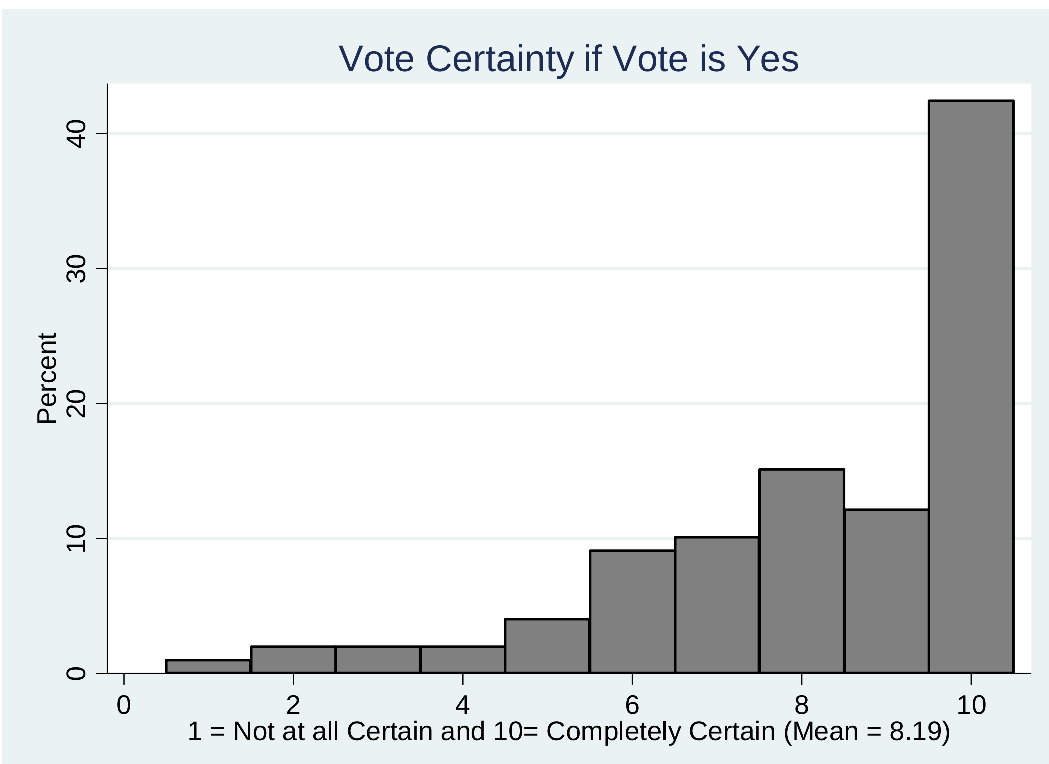
$$\sigma^2 \sim IG(\frac{\gamma_0}{2}, \frac{\gamma_0 s_0^2}{2}).$$

The Gibbs sampler starts with initial values (in our case, the initial values are set =0) and draws β and σ through 10,000 simulations. We drop the initial 1,000 simulations. Unlike ML, because we use MCMC methods to estimate WTP, we don't have to use additional simulation procedures to estimate WTP from the regression coefficients. WTP draws are a product of our estimation.

Respondent Uncertainty

After the WTP question, respondents were asked to rank their certainty of their response on a scale of 1 to 10, where 1 is "Not at all certain" and 10 is "Completely certain." A large body of research exists on reducing hypothetical bias by using certainty responses (see Champ and Bishop, 2000). Hypothetical bias occurs when responses to hypothetical contingent valuation questions do not elicit true values. That is, hypothetical bias occurs when respondents answer a hypothetical question in a way that is inconsistent with their actual behavior. Champ and Bishop performed a split sample experiment where some respondents were asked their WTP to invest in wind energy for one year, while others were offered a hypothetical opportunity. Champ and Bishop find evidence of hypothetical bias—the WTP of the respondents with the hypothetical opportunity is higher than those with the actual investment opportunity. However, when respondents who were less certain of their answer to the hypothetical WTP question were coded as voting "no," the hypothetical bias was eliminated. Therefore, we choose to follow the approach suggested in Champ and Bishop (2000), and applied by Li et al. (2009). We present results with the raw data, and with WTP responses recoded as "no" for those with certainty levels less than 6 and 7. Figure 14 shows the distribution of vote certainty if the respondents voted "yes" on the WTP question. Estimations using the raw data will include all "yes" votes. Estimations of our "7+" models re-code those respondents with a certainty of less than 7 as "no" votes. Estimations for our "8+" models re-code those respondents with a certainty of less than 8 as "no" votes.

Figure 14: Vote Certainty if Vote is "Yes"



Hypothesis Tests

Estimated Coefficients

We have several hypotheses to test using estimated coefficients from the WTP function. First, we propose respondents who are relatively more concerned about the economy will be less likely to vote "yes" on the WTP question. Therefore, we test

(7)

$$H_O: \beta_{ECONOMY} > 0$$

against the alternative that relative concern about the economy does not impact the probability of voting "yes" on the WTP question.

We also hypothesize that respondents who are highly concerned about U.S. dependence on foreign sources of energy are more likely to be WTP to invest in research and development in solar energy because it may reduce future foreign dependence. Therefore we test:

(8)

$$H_O: \beta_{DEPENDENCE} > 0$$

against the alternative that relative concern about dependence on foreign sources of energy does not impact the probability of voting "yes" on the WTP question.

Because solar energy is environmentally sustainable, we hypothesize respondents who believe that nature is fragile and easily damaged are more likely to be willing to pay to invest in solar energy as an alternative to non-renewable sources, leading us to test:

(9)

$$H_O: \beta_{NATURE} > 0$$

against the alternative that beliefs about the fragility of nature do not impact the probability of voting "yes" on the WTP question.

Our survey investigates whether concerns or beliefs about global climate change impact respondents WTP to invest in alternative energy resources. If respondents believe that human behaviors are contributing to global climate change, one way we can mitigate climate change is through sustainable energy sources. Therefore, we test the hypothesis that:

(10)

$$H_O: \beta_{GLOBAL\ TEMP} > 0$$

against the alternative that beliefs in global climate change do not impact the probability of voting "yes" on the WTP question.

Treatment of Uncertain Responses

As discussed in Li et al. (2009) and Champ and Bishop (2000) treatment of uncertain responses impacts WTP estimates. We will also examine if WTP without re-coding uncertainty responses is statistically different from WTP with uncertainty re-coding. Thus, we test:

(11)

$$H_O: WTP_{Full\ Dataset}=WTP_{Certainty\ 7+}$$

and

$$H_O: WTP_{Full\ Dataset}=WTP_{Certainty\ 8+}$$

If we reject the null hypothesis, we can conclude that inclusion of uncertain responses results in hypothetical bias.

Method of Estimation

We also estimate WTP using two different types of estimation—Maximum Likelihood and Bayesian estimation. We would also like to investigate whether WTP is sensitive to method of estimation. Therefore, we test the hypothesis that:

(12)

$$H_O: WTP_{ML}=WTP_{Bayesian}$$

against the alternative that the two methods of estimation provide us with different values of WTP.

Results

Several specifications of independent variables were attempted. Many of possible independent variables are highly correlated, and therefore we chose only a subset of the attitudinal and demographic variables available. Table 1 shows correlations for the attitudinal variables. We show specifications using the following independent variables: BID, ECONOMY, DEPENDENCE, NATURE, INCOME, GLOBAL TEMP. Table 2 provides summary statistics and descriptions of the independent variables included in our reported models.

The Maximum Likelihood regression results are shown in Table 3.[7] Models (1), (4) and (7) use all the data with "yes" responses coded as "yes" votes on the WTP question regardless of respondent certainty. Models(2), (5) and (8) have votes with certainty levels equal to 7 or greater coded as "yes," and all other votes coded as "no." Models (3), (6) and (9) have votes with certainty levels equal to 8 or greater coded as "yes," and all other votes coded as "no." We use the Krinsky Robb (1986) procedure to calculate WTP with 5,000 draws. Table 3 also shows WTP from each of the models. WTP is significantly higher in the model with the full dataset counting uncertain responses as "yes." The WTP in the models with re-coded certainty responses is significantly lower than WTP with the full dataset. We find the changes in WTP relative to uncertainty re-coding to be robust to different specifications of explanatory

[7] The author is grateful for the use of code by Jeanty (2007) to calculate Krinsky Robb estimates of WTP, confidence intervals, and Achieved Significance Levels (Loomis and Elkstrand, 1998)

variables. The confidence intervals on WTP are reported in the bottom row of Table 3. The significance levels on WTP are obtained from hypothesis tests with the H_O: WTP ≤ 0. Models 7, 8, and 9 provide the most conservative estimates of WTP. Figure 15 shows the distributions of the draws of WTP from the Krinsky Robb draws for Models 7, 8, and 9. Note that the distribution of WTP gets relatively less noisy when the uncertain responses are eliminated.

Table 1: Correlations of Level of Concern and Importance Likert Scale Variables

	security	health	airwaterq	economy	future	avail	cost	dependence	energy	env
Threats to national security	1.00									
Delivery and cost of healthcare	-0.02	1.00								
Air and water quality in Arizona	-0.02	0.42	1.00							
The economy, including jobs and inflation	0.26	0.29	0.32	1.00						
The future predictability of energy prices	0.19	0.34	0.20	0.38	1.00					
The future availability of energy	0.20	0.39	0.38	0.30	0.58	1.00				
The future cost of energy	0.17	0.50	0.22	0.30	0.67	0.63	1.00			
Reduction of U.S. dependence on foreign sources of energy	0.35	0.29	0.30	0.30	0.46	0.54	0.52	1.00		
How important are energy issues to you?	0.23	0.33	0.44	0.31	0.56	0.66	0.54	0.62	1.00	
How important are environmental issues to you?	-0.23	0.42	0.60	0.15	0.26	0.37	0.25	0.23	0.42	1.00

Table 2: Definitions and Summary Statistics of Explanatory Variables

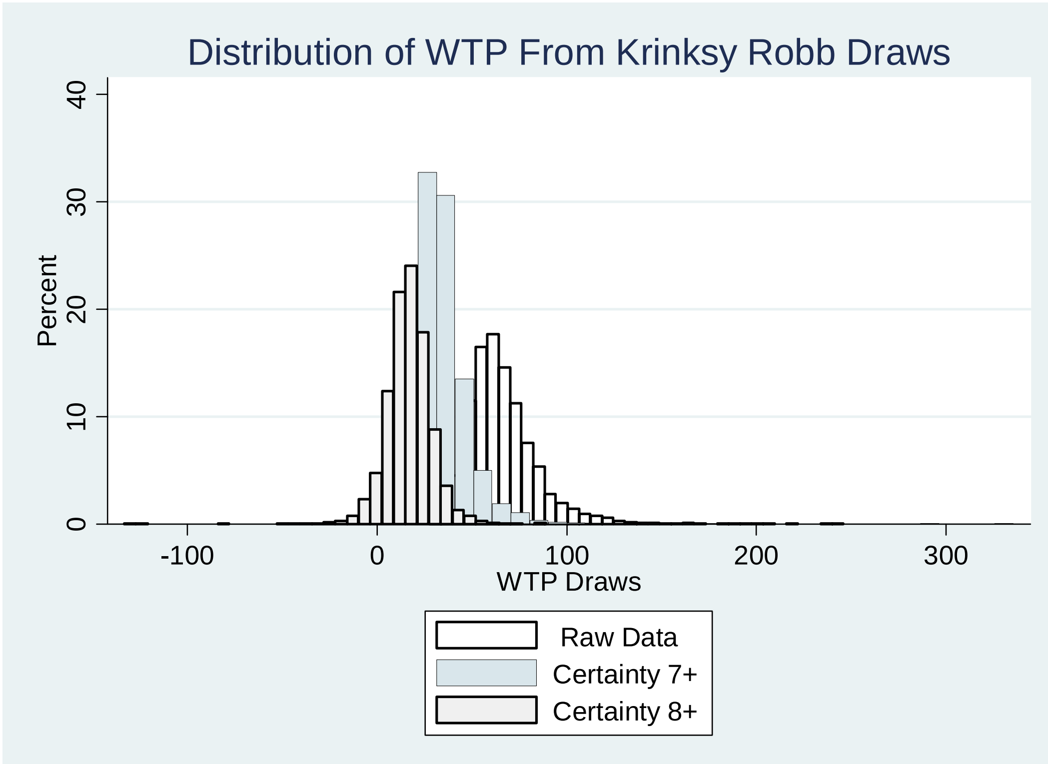
Variable	Mean	Standard Deviation
BID Randomly assigned bid amount ($US2009-10) Bids varied from $0.50, 1,2,4,6,8,10,20,30,40,50,80,100,150,200	$26.15	46.53
ECONOMY Please rate your level of concern about the issues using a scale from one to five, where one means you are not at all concerned, and five means you are extremely concerned: *The state of the economy, including jobs and inflation*	4.39	0.72
DEPENDENCE Please rate your level of concern about the issues using a scale from one to five, where one means you are not at all concerned, and five means you are extremely concerned: *U.S. dependence on foreign sources of energy*	4.43	0.83
NATURE On a scale from one to give, where one means that nature is not easily damaged and five means nature is easily damaged, how do you view nature?	3.60	1.04
INCOME Including all household earners, what was your household income (before taxes) last year? ($US 2008) (1) Less than $20,000; (2) 20-29,999; (3) 30-39,999; (4) 40-49,999; (5) 50-59,999; (6) 60-69,999; (7) 70-79,999; (8) 80-89,999; (9) 90-99,999; (10) 100-149,999; (11) Greater than $150,00	6.33	3.26
GLOBAL TEMP As you know, there is an ongoing scientific and policy debate about global climate change, and in particular, greenhouse gases. In your view, are greenhouse gases, such as those resulting from the combustion of coal, oil, natural gas, and other materials causing average global temperatures to rise?	0.53	0.50

Table 3: Maximum Likelihood Estimation Results

Variables	(1) Full Dataset	(2) Certainty 7+	(3) Certainty 8+	(4) Full Dataset	(5) Certainty 7+	(6) Certainty 8+	(7) Full Dataset	(8) Certainty 7+	(9) Certainty 8+
BID	-0.0129***	-0.0123***	-0.0126***	-0.0117***	-0.0117***	-0.0119***	-0.0140***	-0.0124***	-0.0127***
	(0.00372)	(0.00391)	(0.00396)	(0.00352)	(0.00381)	(0.00386)	(0.00358)	(0.00369)	(0.00380)
ECONOMY	-0.0332	0.0872	0.179	-0.00857	0.108	0.198	-0.0380	-0.0106	0.0857
	(0.198)	(0.192)	(0.191)	(0.194)	(0.191)	(0.190)	(0.197)	(0.183)	(0.184)
DEPENDENCE	-0.183	0.139	0.171	-0.103	0.160	0.194	-0.195	0.131	0.164
	(0.187)	(0.158)	(0.155)	(0.174)	(0.156)	(0.154)	(0.184)	(0.152)	(0.151)
NATURE	0.357**	0.195	0.227				0.533***	0.359***	0.341***
	(0.170)	(0.154)	(0.151)				(0.145)	(0.123)	(0.122)
INCOME	0.0492	0.0519	0.0414	0.0286	0.0419	0.0311	0.0509	0.0499	0.0389
	(0.0431)	(0.0405)	(0.0394)	(0.0411)	(0.0396)	(0.0387)	(0.0424)	(0.0382)	(0.0378)
GLOBAL TEMP	0.568*	0.798***	0.589*	0.938***	1.015***	0.846***			
	(0.320)	(0.308)	(0.306)	(0.266)	(0.257)	(0.255)			
Intercept	-0.110	-2.041*	-2.723**	0.596	-1.592	-2.177**	-0.343	-1.757*	-2.378**
	(1.137)	(1.089)	(1.094)	(1.051)	(1.018)	(1.017)	(1.125)	(1.031)	(1.046)
Observations	118	118	118	118	118	118	122	122	122
WTP	$66.29***	$34.74***	$17.74*	$68.60***	$35.14***	$17.61*	$63.81***	$32.34***	$16.94*
Conf. Interval	[42.42,131.59]	[13.43,76.78]	[-7.89,43.37]	[43.02,146.23]	[13.34,81.44]	[-9.09,45.19]	[42.64,113.47]	[12.48,68.08]	[-6.63,41.03]

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Figure 15: WTP Draws for ML Models 7, 8, and 9



The Bayesian estimation results are presented in Table 4. Because WTP is relatively robust to specifications including both NATURE and GLOBAL TEMP using ML, we estimated the Bayesian models using the full set of explanatory variables. The mean WTP from the Gibbs draws and the corresponding confidence interval are also reported in the bottom rows of Table 4. WTP follows the same pattern relative to certainty coding as in ML estimations—the more restrictive we are with our uncertainty re-coding, the lower the mean WTP. Figure 16 shows the distributions of the draws of WTP from the Bayesian models.

Revisiting our hypotheses, we find that the estimated coefficient on ECONOMY is not statistically significant with any of our specifications, therefore, we fail to reject the H_O in equation (7) and conclude that respondents with high levels of concern about the economy are not necessarily less likely to vote "yes" on the WTP question. We also find that the estimated coefficient on DEPENDENCE is not statistically significant with any of our specifications, so we fail to reject the H_O in equation (8) and conclude that respondents who are highly concerned about U.S. dependence on foreign sources of energy are not necessarily more likely to vote "yes" on the WTP question . With our ML estimations, the estimated coefficient on NATURE is statistically significant using the full dataset, but not with uncertainty re-coding when the full set of explanatory variables is included. However, when GLOBAL TEMP is dropped from the ML specification, NATURE becomes statistically significant with uncertainty

Figure 16: WTP draws for Bayesian Models 10, 11, and 12

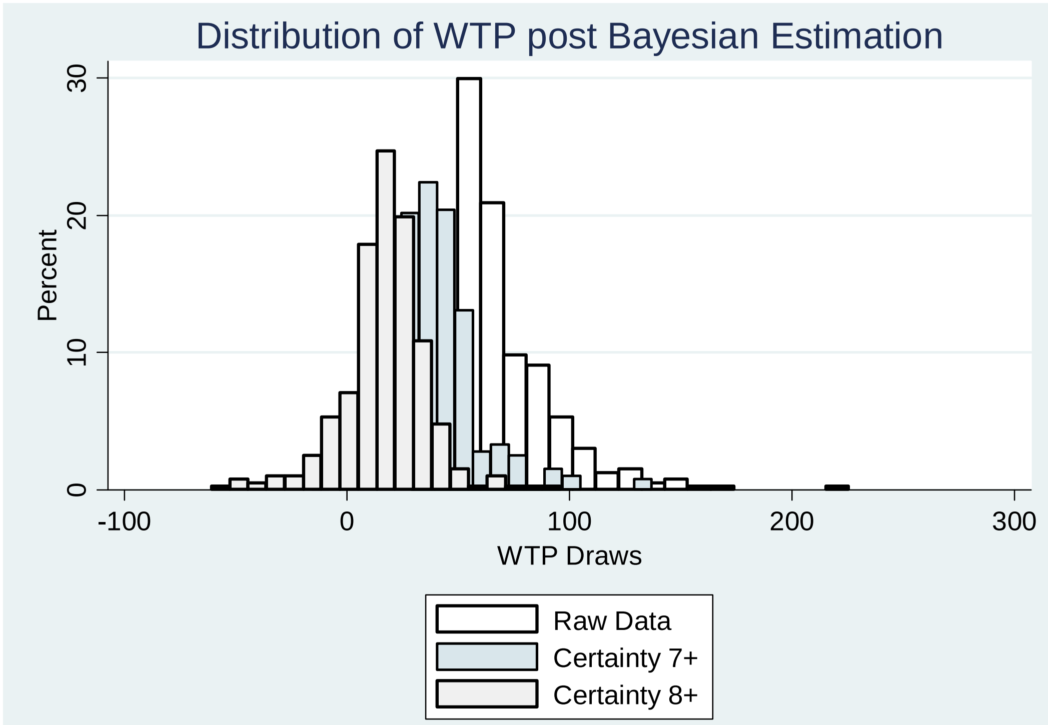


Table 4: Bayesian Estimation Results

Variables	(10) Full Dataset	(11) Certainty 7+	(12) Certainty 8+
BID	0.022135***	-0.010487***	-0.010405***
	(1.0712)	(0.0035)	(0.00391)
ECONOMY	-0.010487	-0.037775	0.147963
	(0.0035)	(0.1972)	(0.1855)
DEPENDENCE	-0.037775	-0.12455	0.117494
	(0.1972)	(0.1656)	(0.1542)
NATURE	-0.12455*	0.254736	0.191783
	(0.1656)	(0.1589)	(0.1516)
INCOME	0.254736	0.48116	0.477532
	(0.1589)	(0.3142)	(0.3051)
GLOBAL TEMP	0.48116**	0.033153*	0.027538*
	(0.3142)	(0.0400)	(0.0386)
Intercept	0.033153	0.022135*	-2.102225**
	(0.0400)	(1.0712)	(1.0448)
Observations	118	118	118
WTP	$72.24***	$37.57***	$17.03***
Conf. Interval	[67.13, 77.33]	[35.93,39.19]	[16.25,17.79]

re-coding. With Bayesian estimation, the estimated coefficient on NATURE is also only statistically significant while using the full dataset, and becomes insignificant with uncertainty re-coding. Because we have evidence to show that hypothetical bias exists in the models without certainty re-coding, we conclude that NATURE does not have a statistically significant impact on probability of voting "yes" on the WTP question. Therefore, we fail to reject the null hypothesis in equation (9) for our best empirical specifications. The estimated coefficient on GLOBAL TEMP is statistically significant and positive in all specifications, indicating that respondents who believe that global climate change is occurring are more likely to vote "yes" on the WTP question. We thus reject the null hypothesis in equation (10) and conclude that people who believe that humans are impacting the global temperature are more likely to vote "yes" on the WTP question.

We test for equality of means between the WTP using the full dataset versus the WTP using the different certainty levels. We reject the H_O in equation (11) for all tests with a level of 0.01 and conclude that we have sufficient evidence to show the mean WTP with uncertainty re-coding is statistically different than the mean WTP when including the uncertain responses. Therefore, failure to re-code the data based on respondent uncertainty results in hypothetical bias with our data.

We also test for equality of means between the WTP obtained using Bayesian estimation relative to the WTP using ML estimation. We compare the WTP from the models with equivalent uncertainty coding and sets of explanatory variables. We fail to reject the null hypothesis of equality of WTP in all three cases, even at a 10% level of significance. Therefore, we can conclude that method of estimation does not result in statistically significant differences in WTP estimates.

Conclusions

This paper contributes to the existing body of research into WTP to invest in research and development in solar energy in several ways. First, we find that the average household in Arizona would be WTP approximately $17 a month to invest in research and development in solar energy in Arizona. In 2005, there were 2.2 Million households in Arizona. Our study indicates that Arizonans would be willing to pay a total 34.7$M to invest in solar energy. Therefore, our data provide strong evidence for the existence of large non-market benefits of solar energy investment. Our estimated WTP value is significantly higher than the average of $3.66 for U.S. residents found in Li et al. (2009), indicating that Arizona residents' preferences may vary relative to residents of other states in the U.S. In addition, we find large and statistically different deviations in WTP estimates when we change our uncertainty coding. Individual WTP estimates without uncertainty corrections were inflated by as much as $55. Our study shows failure to account for respondent uncertainty can lead to overestimates of WTP with policy-relevant consequences. We also compare WTP estimates using ML and Bayesian estimation of the probit model and find no statistically significant difference in WTP due to method of estimation. Our data study suggest that our WTP estimates are quite robust to method of estimation. Thus, our study highlights the need to investigate differences in preferences based on regions in the U.S., the necessity of careful investigation of respondent uncertainty, and the relative robustness of ML and Bayesian estimations, even with a small sample.

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Appendix A: Willingness to Pay Question

SOLAR ENERGY IN ARIZONA

The state of Arizona has the highest potential for solar energy generation in the United States. Arizona is one of 26 states to enact a Renewable Energy Standard which requires that by 2025, 15% of the energy generated in Arizona must be from renewable resources such as solar.

Current costs of solar energy are higher than non-renewable energy, yet increased research and development into renewable technologies could lower future costs of solar energy. We want to know your opinions about solar energy generation and investment in solar research and development in Arizona.

II. Your Chance to Vote

Obtaining energy from renewable resources in Arizona will reduce U.S. dependence on foreign oil and also reduce emissions of greenhouse gases and other pollutants. One-hundred fifty percent of Arizona's demand for electricity could be met using only solar energy. However, solar technologies remain costly to implement, and are rarely in use.

Suppose that a statewide referendum was held today. You could advise the Arizona State Government (Governor and Legislature) to levy a fee on residential energy users such as yourself. The money collected would be dedicated to increase the research and development of specific solar technologies suited to Arizona.

By law the money collected from this fee could only be used for these purposes. The increased fees would cost your household ________$ per month on your electricity bill.

1. If you were confident that all fees collected would directly be spent on increased research and development of specific solar technologies suited to Arizona, would you vote in favor of the referenda?

❐ YES ❐ NO

2. How certain are you of your answer to question 1 above?

Not at all certain ->> ->> Completely certain

0 1 2 3 4 5 6 7 8 9 10