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Willingness to Pay for Agricultural Research and Extension Programs

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ABSTRACT

The North Carolina Agriculture Survey was designed to estimate the willingness to pay for agricultural research and extension programs. We find that North Carolina households are willing to pay between \$218 and \$401 million for food production programs and between \$251 and \$698 million for water quality programs annually. We find evidence of divergent validity and differences in the willingness to pay estimates from the single-bound and multiple-bound data.

Key Words: *agricultural research and extension programs, contingent valuation, divergent validity, multiple bound questions, single bound questions.*

The North Carolina State University (NCSU) College of Agriculture and Life Sciences (CALS) has several goals. Two of these goals are to seek new knowledge through the North Carolina Agricultural Research Service and extend educational programs through the North Carolina Cooperative Extension Service. The 1998 North Carolina Agriculture (NCAG) Survey was designed to gather information so as to better understand the benefits of CALS research and extension programs to North Carolina residents. Previous research into the benefits of agricultural research has estimated the market benefits by the contribution of research expenditures to agricultural output and revenue (Norton, Coffee, and Frye; Leiby and Adams; Huffman and Just). For example, using a production function approach Leiby and Adams find that estimates of the internal rate of return to Maine Agricultural Extension Service research expenditures are high, providing evidence of the underinvestment in agricultural research.

The contingent valuation method was developed to estimate the nonmarket benefits of a variety of projects and programs (Mitchell and Carson). A relatively new application of contingent valuation is to the valuation of the spillover benefits of agricultural research and extension programs. The NCAG survey contains contingent valuation questions that elicit the willingness to pay for food production and water quality research and extension programs. In a similar effort, Swallow and Mazzotta estimate the public good benefits of Rhode Island Agricultural Experiment Station programs with hypothetical survey methods. Swallow and Mazzotta find that willingness to pay is substantially greater than the average cost of agricultural experiment station programs to Rhode Island households.

While agricultural research expenditures

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increased by 31 percent from 1982 to 1997, the federal formula share of funding declined from 50 percent in 1982 to 30 percent in 1997 (Perry). Funding from private sources has significantly increased. There is much concern about this trend in agricultural research funding (Huffman and Just; Norton, *et al.*). Huffman and Just investigated the perceived benefits of alternative funding mechanisms among agricultural experiment station scientists. They find that the scientists perceive that federally funded projects generate geographic spillovers, state funded projects primarily benefit those within the state, and privately funded research primarily benefits the private source of the funds. One concern is that the increased private funding will diminish positive spillovers from agricultural research. The NCAG survey focuses on a hypothetical reduction in federal agricultural research funding. Survey respondents are asked for their willingness to pay for state funding of the current level of agricultural research and extension. In this way, we estimate the spillover benefits of agricultural research funding.

The NCAG survey also allows us to explore two issues in contingent valuation methodology. Since its first implementation, researchers have been concerned about the validity of the contingent valuation method. Much research has examined convergent validity by comparing willingness to pay estimated from contingent valuation and other methods (Carson, *et al.*). Little research has explored the divergent validity of contingent valuation. Divergent validity exists when different public goods and/or valuation scenarios generate different valuation responses (Smith). Using split-samples in a telephone survey we conduct contingent valuations for research and extension programs focused on food production or water quality. A single sentence in the telephone survey script is used to differentiate the two programs. We compare the willingness to pay and determinants of willingness to pay for the two programs.

The most popular survey design for eliciting willingness to pay is the dichotomous choice, or single-bound, question. With dichotomous choice contingent valuation respondents are asked whether they would be willing to pay a single price for the public good. This question is relatively easy to answer for respondents but provides a limited amount of information. Contingent valuation researchers have experimented with double-bound valuation questions in which follow-up willingness-to-pay questions with different dollar amounts are presented (Hanemann, Loomis, and Kanninen). A typical result is that double-bound valuation questions increase the efficiency of valuation with a divergence between first-bound and second-bound willingness to pay distributions (Cameron and Quiggin). A variety of multiple-bound question formats have been developed ranging from multiple payment card questions (Welsh and Poe) to iterative bidding questions (Langford, Bateman, and Langford). We use iterative bidding multiple-bound data where respondents may answer as many as eight referendum questions. We compare the single-bound and multiple-bound willingness to pay.

Willingness to Pay for Research and Divergent Validity

Respondents are assumed to answer willingness-to-pay questions based on the value they place on the offered programs. To define this value, consider a household utility function, U, that depends on a consumer good composite commodity, X, food production research and extension programs, FP, and water quality research and extension programs, WQ

$$(1) \quad U = U(X, FP, WQ).$$

Utility is increasing in X, FP, and WQ and twice differentiable. The minimization of expenditures, PX, subject to the utility constraint, $U^* = U(X, FS, WQ)$, leads to the expenditure function, M,

$$(2) \quad M = M(P, FS, WQ, U^*)$$

where P is the market price of consumer goods and FP and WQ are at their current levels.

When faced with the elimination of the research and extension programs (FP = 0, WQ

= 0), the willingness to pay to avoid elimination is the difference in expenditure functions

$$\text{(3)} \quad WTP[FS] = M(P, 0, WQ, U^*) - M(P, FP, WQ, U^*)$$

$$\text{(4)} \quad WTP[WQ] = M(P, FP, 0, U^*) - M(P, FP, WQ, U^*)$$

The sum of equations (3) and (4) is not necessarily equal to the willingness to pay to avoid loss of both programs. The value of both programs is WTP[FP, WQ] = M(P, 0, 0, U)—M(P, FP, WQ, U). The sum of the separate values of the food production and water quality programs will be an overestimate if FP and WQ are substitutes. The sum of the separate values will be an underestimate if FP and WQ are complements (Hoehn).

One test for divergent validity is whether willingness to pay for food production and water quality are the same. The null hypothesis is WTP[FP] = WTP[WQ] and the alternative hypothesis is WTP[FP] $\neq$ WTP[WQ]. Note that it is plausible that the willingness to pay values for food production and water quality are the same. Therefore, a rejection of the null hypothesis does not necessarily indicate the absence of divergent validity. Another test of divergent validity is for whether the determinants of WTP are similar. In this test we might expect that tastes and preferences and other factors affecting willingness to pay will be different for different programs. For example, those who are more interested in environmental issues will be willing to pay more for water quality programs. Those who are more interested in agricultural issues or who are closely associated with the rural economy will be more willing to pay for food production programs. Equality of coefficient vectors would indicate the absence of divergent validity.

Single- and Multiple-Bound Valuation Questions

The 1998 NCAG telephone survey of residents of all 100 counties in North Carolina had a completion rate of 66 percent. The full sample contains 897 cases. Survey respondents were described the types of agricultural research conducted by the CALS through a series of knowledge and attitudinal questions. Seventy-nine percent of respondents state that "research on problems facing our state" by NCSU is very important. Fifty-nine percent state that "off-campus extension work" by NCSU is very important. After being told that the Agricultural Research Service does research on food, fiber and natural resources, only 44 percent of respondents report that they had heard about it or the Agricultural Experiment Station. In contrast, 71 percent report that they had heard about the Cooperative (or Agricultural) Extension Service after being told that it provides education and information outside the classroom.

Next, respondents were told about the areas in which the CALS conducts research and extension programs. These areas are protecting the environment, keeping food prices as low as possible, helping farmers stay in business, ensuring that food is safe and nutritious, helping families, working with public schools and youth, and maintaining viable communities. Most respondents (68 percent–93 percent) felt that each of the areas was "very important." Protecting the environment, helping farmers stay in business, ensuring that food is safe and nutritious each were considered very important by more than 80 percent of the sample. The most popular programs related to food production and safety. Maintaining viable communities had the lowest importance among the survey respondents.

The contingent valuation section of the NCAG survey presents survey respondents with a hypothetical situation. One-half of the respondents received the food production scenario: "We already pay for research and extension programs within the College of Agriculture and Life Sciences at N.C. State University through federal, state, and local taxes. *Some of these programs help increase and improve food production.* However, federal funding levels are currently threatened. NC State University will need more state money if these programs are to continue." The other one-half of respondents received the water quality scenario in which the highlighted sentence above was replaced with: "*Some of these programs help protect water quality for drinking and recreation.*" The food production and water quality scenarios are designed to elicit the willingness to pay to avoid elimination of the respective research and extension program.

Next respondents are asked whether they would be willing to pay to prevent a closure of the program. "Would you and your household be willing to pay \$A each year in higher state taxes, for these programs, if you knew the money would be used for research and extension programs?" The dollar amount (\$A1) took on eight values with a random start ranging from \$10 to \$200. The eight values were \$10, \$25, \$50, \$75, \$100, \$125, \$150, \$200. In a small telephone pretest, respondents were presented the willingness to pay questions with \$A1 = \$200. Over three-quarters of respondents answered no to the initial willingness to pay question. We concluded that the \$200 upper limit was sufficiently high.

If a respondent answers "Yes" to the willingness to pay question for \$A1, the next question asks whether the respondent is willing to pay \$A2, where \$A2 is the next highest dollar amount in the range of values. Follow-up valuation questions continue, increasing the dollar amount until the respondent answers "No" or the \$200 upper limit is reached. If a respondent answers "No" to the willingness to pay question for \$A1, the next question asks whether the respondent is willing to pay the next lowest dollar amount. Follow-up valuation questions continue, decreasing the dollar amount until the respondent answers "Yes" or the \$10 lower limit is reached.

The null hypothesis is that the willingness-to-pay estimates from the initial willingness-to-pay question and the follow-up questions will be equal. This hypothesis will not be rejected if the optimal response to the initial and follow-up willingness-to-pay questions is truth telling. However, Carson, Groves, and Machina argue, in the double-bound context, that follow up willingness-to-pay questions will lead to a downward shift in willingness-to-pay estimates when compared to the willingness-to-pay estimates from the first question. Their arguments are naturally extended to the case of the multiple-bound question format. For example, respondents who answer Yes to the first (second, etc.) willingness-to-pay question are presented with a second (third, etc.) willingness-to-pay question with a higher price. This may introduce uncertainty about the true cost of the program. This uncertainty will lead risk averse respondents to answer No to follow-up willingness-to-pay questions.

For respondents who answer No to the first (second, etc.) willingness-to-pay question the subsequent lower price in the second (third, etc.) question might introduce a bargaining effect. A seller who lowers the initial offer price may be willing to lower it again. If respondents interpret the lower price as the initiation of bargaining, the optimal response is to continue to answer No until the offer price is at its minimum. While not mentioned by Carson, Groves and Machina, note also that the bargaining interpretation also applies to initial Yes respondents. If Yes respondents interpret their initial Yes response as the purchase of the program, a seller who then raises the price without a corresponding increase in quantity or quality of the program is simply trying to extract surplus from the consumer. The optimal response to the follow-up question is, again, No.

Carson, Groves and Machina offer several other interpretations of the follow-up willingness-to-pay questions. Each of these interpretations suggests that the optimal follow-up response is generally No. This leads to the alternative hypothesis that the willingness-to-pay estimates when the follow-up question data are included will be lower than the willingness-to-pay estimate when only the initial question data are included.

Empirical Comparison of Single- and Multiple-Bound Models

The probability of a Yes response to the single-bound question depends on the probability that WTP with random error is greater than the dollar amount

(5) $\Pr(\text{YES}) = \Pr(\text{WTP} + e > \text{A1})$.

When e is distributed normally the discrete choice econometric model is the probit model. The probability of a Yes response will vary inversely with A1 if the respondent behaves rationally. The dependent variable for this analysis is YES1

(6) $\text{YES1} = x_i'\phi + \epsilon$

where YES1 is a dummy dependent variable equal to one (zero) if WTP + e > (<) A1, x is a vector of independent variables, ϕ is a vector of the probit coefficients, and ϵ is a normally distributed error term. Mean WTP is estimated at the means of the independent variables using the procedures described in Cameron and James. The Delta Method is used to analytically construct WTP standard errors (Cameron; Greene).

Willingness-to-pay interval data is formed from the multiple-bound questions. For example, a respondent who says Yes to the dollar amounts \$25 and \$50 but No to \$75 is assumed to have a WTP value between \$50 and \$75. Upper, A_U, and lower, A_L, bounds on WTP are formed for each respondent. The interval data approach specifies that the probability that WTP is between the lower and upper bounds is

(7) $$\Pr(\text{WTP} \subset [A_L, A_U]) = \Pr([A_L - \text{WTP}] < z < [A_U - \text{WTP}])$$

where z is the standard normal random variable. Interval data regression techniques are used (Cameron and Huppert, 1989; Greene, 1998)

(8) $W = x_i'\delta + \upsilon_i$

where W is an indicator variable for the latent WTP value, δ is a vector of regression coefficients and υ_i is the error term. The indicator variable is equal to $W = 1, \ldots, 9$ corresponding to the various upper and lower bounds on WTP. Willingness to pay is estimated at the mean of the independent variables. The Delta Method is used to analytically construct the WTP standard errors (Greene).

In the case of double bound data, the choice of estimation technique is between the bivariate probit model (Cameron and Quiggin) and the interval data model. The bivariate probit model allows estimation of (i) willingness to pay for each question and (ii) the correlation in the errors of the willingness to pay estimates. The interval data model constrains (i) the willingness to pay estimates to be equal across question and (ii) the correlation in error terms to one. Alberini describes the potential bias in willingness to pay estimates when adopting the interval data model but finds that it may be preferred to the bivariate model even when the correlation in error terms across willingness-to-pay estimates is low. In the case of multiple-bound data, the multivariate probit model is the natural extension to the bivariate probit model. Unfortunately, in this application the number of follow-up questions answered by each respondent is different, making the multivariate probit model inappropriate. Given the results of Alberini we proceed with the interval data model.

Data

The contingent valuation analysis is conducted with 880 observations (Table 1). Most of the 17 discarded cases are due to missing values on an independent variable other than income. Only two respondents answered "Don't know" to the willingness-to-pay questions and were discarded. A regression model is used for imputing missing income values. The model was run with 801 cases and was specified with standard independent variables including education, experience, experience squared, race and gender. Dummy variables are included to account for regional differences and political party affiliation. The dependent variable is the log of the household income. Missing income data was replaced with the midpoint of the income interval closest to the predicted income value for 79 cases. The average household income for the full sample, INCOME, is \$45.93 (in thousands of 1998 dollars). The average income is not statistically different across the

Table 1. Summary of Data

	Food Production		Water Quality	
Variables	Mean	Standard Deviation	Mean	Standard Deviation
INCOME	46.79	35.72	45.07	30.82
EDUC	14.64	3.49	14.49	3.44
WHITE	0.82	0.38	0.83	0.38
MALE	0.50	0.50	0.49	0.50
AGE	48.09	15.78	47.31	16.06
OWNFARM	0.25	0.44	0.28	0.45
AGRICULT	0.38	0.49	0.36	0.48
ENVIRONM	0.61	0.49	0.57	0.50
Sample Size	439		441	

food production and water quality sub-samples (Table 1).

Other demographic variables are EDUC, AGE, MALE, and WHITE. None of the demographic variables are statistically different across the food production and water quality sub-samples. EDUC is the respondent's education level measured by the number of years of schooling. The average education level is 14.56 years. AGE is the respondent's age in years. The average age is 47.7 years. MALE is the respondent's sex and is equal to 1 if male and 0 if female. Forty-nine percent of the sample is male. WHITE is equal to 1 if the respondent is white and 0 if otherwise. Seventeen percent of the sample is non-white.

Three variables measure preferences for food production and water quality programs. OWNFARM is equal to 1 if the respondent (or a relative) currently owns or operates a farm and 0 otherwise. Twenty-six percent of the sample are farm owners or related to one. Respondents were asked if they were very interested, moderately interested, or not at all interested in "agricultural or farm issues" and "environmental issues." Respondents who said that they were very interested in either of these are considered having preferences for these issues. Overall, 37 percent of respondents are very interested in agricultural issues (AGRICULT) and 59 percent are very interested in environmental issues (ENVIRONM). None of these variables is statistically different across the food production and water quality sub-samples.

The Yes/No response to the first dollar amount (A1) is first analyzed by presenting the percentage of Yes responses at each dollar amount (Table 2). For the food production scenario, as the dollar amount increases from \$10 to \$200 the yes responses fall from 89 percent to 37 percent. For the water quality scenario, the Yes responses fall from 81 percent to 55 percent at \$150 and then, inexplicably, rise to

Table 2. Willingness-to-Pay Frequencies from Single-Bound Data

	Food Production			Water Quality		
Dollar Amount (A1)	YES1	Total	Percent YES	YES1	Total	Percent YES
10	48	54	88.89	47	58	81.03
25	41	58	70.69	37	52	71.15
50	36	52	69.23	37	55	67.27
75	37	57	64.91	38	57	66.67
100	31	53	58.49	33	58	56.9
125	30	58	51.72	29	53	54.72
150	28	55	50.91	29	53	54.72
200	19	52	36.54	34	55	61.82
Total	270	439	61.5	284	441	64.4
χ^2		39.6			14.28	
P-value		0.001			0.046	
Willingness to Pay		\$111.58			\$123.61	
Standard Error		5.06			5.06	

Table 3. Willingness-to-Pay Intervals from Multiple-Bound Data

Lower Bound of Willingness to Pay	Upper Bound of Willingness to Pay	Frequency	
		Food Production	Water Quality
−∞	10	91	91
10	25	53	49
25	50	56	49
50	75	45	48
75	100	37	31
100	125	41	43
125	150	23	15
150	200	24	30
200	∞	69	85
Sample Size		439	441

62 percent at $200. The negative relationship is statistically significant at the .01 level of confidence for the food production scenario (χ^2 = 39.6[7 d.f.]) and the .05 level of confidence for the water quality scenario (χ^2 = 14.28[7 d.f.]).

Holding constant the dollar amount, the frequency of Yes responses by survey version is not significantly different according to the Cochran-Mantel-Hanszel statistic (Snedecor and Cochran). Using this table, the Turnbull lower-bound nonparametric WTP estimates can be found (Haab and McConnell). Willingness to pay is $112 and $124 for the food production and water quality scenarios. The difference in these estimates is marginally significant (t = 1.68).

The frequency distribution of the interval data indicates that the largest number (21 percent) of respondents are not willing to pay the lowest dollar amount (Table 3). Other popular WTP values are between $10 and $25 (12 percent of respondents), between $25 and $50 (12 percent), between $50 and $75 (11 percent) and over $200 (18 percent). The differences in the frequencies of WTP intervals between the food production and water quality scenarios are not statistically significant.

Empirical Results

The probit model with the Yes/No response as the dependent variable supports the result that respondents behave rationally when faced with changes in cost (Table 4). The coefficient on the dollar amount variable (A1) is negative and statistically significant at the .01 level of confidence in the pooled model. Differences in the food production and water quality scenarios are tested with a dummy variable equal to 1 for the food production version (FOOD). The coefficient on the FOOD variable is not statistically different from zero. Other results from the pooled probit model are that the

Table 4. Single-Bound Willingness-to-Pay Models*

	Pooled		Food Production		Water Quality	
	Coefficient	Standard Error	Coefficient	Standard Error	Coefficient	Standard Error
Constant	0.432	0.276	0.679	0.388	0.174	0.402
Dollar Amount (A1)	−0.005	0.001	−0.007	0.001	−0.003	0.001
FOOD	−0.119	0.089				
INCOME	0.004	0.001	0.004	0.002	0.005	0.002
EDUC	0.028	0.014	0.012	0.020	0.041	0.021
WHITE	−0.050	0.119	0.151	0.168	−0.301	0.174
MALE	−0.057	0.092	−0.245	0.133	0.103	0.129
AGE	−0.005	0.003	−0.006	0.004	−0.005	0.004
OWNFARM	0.128	0.106	0.204	0.157	0.036	0.146
AGRICULT	0.116	0.101	0.166	0.144	0.055	0.145
ENVIRONM	0.126	0.094	0.034	0.314	0.208	0.138
Model χ^2	80.49		55.21		40.58	

* Dependent variable = YES1.

Table 5. Multiple-Bound Willingness-to-Pay Models*

	Pooled		Food Production		Water Quality	
	Coefficient	Standard Error	Coefficient	Standard Error	Coefficient	Standard Error
Constant	−15.12	20.92	10.87	28.57	−43.44	29.50
Dollar Amount (A1)	0.62	0.06	0.40	0.08	0.85	0.08
FOOD	−10.68	6.65				
INCOME	0.34	0.11	0.42	0.14	0.34	0.16
EDUC	2.85	1.08	1.00	1.48	4.26	1.53
WHITE	−13.85	8.86	−4.23	12.42	−28.79	12.26
MALE	4.30	6.88	−18.95	9.80	24.76	9.33
AGE	−0.41	0.22	−0.15	0.30	−0.64	0.31
OWNFARM	15.59	7.86	30.00	11.35	−0.90	10.50
AGRICULT	9.88	7.47	8.93	10.39	10.70	10.46
ENVIRONM	16.24	7.08	7.45	9.81	24.48	10.03
σ	93.61	3.14	93.00	4.36	89.78	4.30
LL Function	−1855.11		−942.26		−893.08	

* Dependent variable = willingness-to-pay intervals.

probability of a Yes response increases with income, increases with education, and decreases with age.

The probit regression models from the food production and water quality split-samples indicate that respondents are less likely to respond Yes as the dollar amount increases. In both scenarios, the probability of a Yes response increases with income. In the food production scenario the probability of a Yes response is lower if the respondent is male. In the water quality scenario, the probability of a Yes response increases with education and is lower for white respondents.

None of the agricultural or environmental preference variables is statistically significant in the food production or water quality models. However, the coefficient vectors are significantly different at the .05 level of confidence (χ^2 = 19.86[10 d.f.]). This result is primarily due to the large difference in the coefficient on the price (A1) variable and should not necessarily be attributed to differences in the willingness to pay for food production and water quality programs.

The WTP interval data regression results are similar in terms of the sign of the coefficients but the efficiency of coefficient estimates is higher when compared to the probit models (Table 5). With the pooled data willingness to pay increases with the starting dollar amount. For each $10 increase in the starting amount, WTP increases by $6.20. This result is one indication that respondents may be negatively affected by the cost uncertainty of an increased price. Those who initially answer Yes are likely to answer No to the second willingness-to-pay question with the price increase leading to the starting point bias. The scenario versions do not generate different responses. Other results in the pooled data model are that willingness to pay increases with income, education, if the respondent owns a farm, and if the respondent holds positive preferences toward the environment. Willingness to pay decreases with age.

The split-sample interval regression models indicate that the starting point amount and income are significant determinants of willingness to pay in both food production and water quality scenarios. The effect of the dollar amount on willingness to pay is lower in the food production scenario with only a $4 increase in willingness to pay with each $10 increase in the dollar amount. In the water quality sample, willingness to pay increases by $8.50 with each $10 increase in the dollar amount. Willingness to pay increases by $.42 and $.34 for each $1000 increase in income

Table 6. Willingness-to-Pay Estimates

	Single Bound	
	Food Production	Water Quality
Willingness to Pay	141.55	246.58
Standard Error	12.65	62.25
	Multiple Bound	
	Food Production	Water Quality
Willingness to Pay	76.94	88.61
Standard Error	4.65	4.55

for the food production and water quality scenarios.

In the food production sample, male respondents are willing to pay almost $19 less than female respondents and farm owners are willing to pay $30 more than non-farm owners. Neither the agricultural or environmental preference variables are statistically significant. In the water quality sample, willingness to pay increases by about $4 with each additional year of education, is $28 lower for white respondents, is $25 higher for male respondents, and decreases by $.64 for each additional year of age. Respondents who have environmental preferences are willing to pay between $24 and $25 more than others. The vectors of coefficients from the food production and water quality models are significantly different at the .01 level of confidence (χ^2 = 42.12[10 d.f.]). This result, combined with the differences in coefficients on the preference variables supports a conclusion of divergent validity for the multiple-bound willingness-to-pay question format.

Willingness-to-Pay Estimates

Willingness-to-pay estimates range from $77 to $247 depending on the program and estimation technique (Table 6). From the split-sample probit models, willingness-to-pay estimates are almost $142 and $247 for the food production and water quality programs. This large difference in willingness to pay across programs is not significantly different, however. The willingness to pay for the food production research and extension program is $77 in the multiple-bound model. The willingness to pay for the water quality research and extension program is almost $89 in the multiple-bound model. The difference in willingness to pay across scenario is not significantly different with the multiple-bound data.

The multiple-bound willingness-to-pay estimates are between 40 percent and 60 percent lower than the single-bound willingness to pay estimates. These differences are significant at the .01 level of confidence. This result supports the alternative hypothesis of a negative shift in willingness-to-pay estimates with follow up questions. This result supports the contention that responses to follow-up willingness-to-pay questions are biased downward due to response incentive effects. However, the willingness-to-pay estimates are measured with more precision with the interval data models. The ratios of willingness to pay to the standard errors are 50 percent to 200 percent larger with the interval data than with the binary data. This is because more information is obtained from respondents with the follow-up valuation questions. With the single-bound data we only know whether willingness to pay is above or below a single threshold. With the interval data, we know the upper and lower bounds that willingness to pay falls within.

Conclusions

In this paper we estimate the value of federally funded agricultural research and extension programs in North Carolina. The lower estimates of household willingness to pay for the food production and water quality research and extension programs are $77 and $89, respectively. The higher estimates of household willingness to pay are $142 and $247 for the food production and water quality research and extension programs, respectively. With about 2.83 million households in North Carolina (North Carolina Office of State Planning) and depending on the methodology adopted, the annual aggregate value of CALS food production research and extension programs range from $218 to $401 million. The annual aggregate value of CALS water quality research and extension programs range from \$251 to \$698. These estimates of the non-market benefits of research and extension programs can be compared to the costs of these programs to determine their economic efficiency.

The NCAG survey allows the exploration of two methodological issues in contingent valuation. In a nonparametric test of the divergent validity of contingent valuation we find that willingness-to-pay estimates are marginally different. In our parametric tests we find that the willingness-to-pay estimates are not significantly different when measured with the single-bound or multiple-bound data. With the single-bound data, this may be a result of the large confidence interval on the willingness-to-pay estimate for the water quality program. The large confidence interval results from the relative lack of variation in the proportion of Yes responses as the price rose from \$10 to \$200 and the increase in Yes responses at the highest price. While we pre-tested willingness-to-pay responses with the highest price, in hindsight the range of price amounts should have been wider. A wider range of price would help to locate the average willingness-to-pay amount more efficiently.

The determinants of willingness to pay are statistically different in the single-bound models but the result does not lead to a convincing conclusion of divergent validity. In the multiple-bound models, the determinants of willingness to pay are significantly different across valuation scenario and the differences are in the expected direction. Households that own farms are willing to pay more for food production programs than other households. Households that have environmental preferences are willing to pay more for the water quality programs. Overall, these results provide some evidence that the willingness-to-pay estimates are divergent valid measures of economic benefits.

In our comparison of single- and multiple-bound (follow-up) data we find significant differences in the two approaches. Willingness to pay is measured with much greater precision when using the follow-up data. However, we find that single-bound valuation questions produce willingness-to-pay estimates that are much larger than those from multiple-bound valuation questions. Also, we find that the willingness-to-pay estimates from the multiple-bound data suffer from starting point bias. These results support the contention that responses to follow-up willingness-to-pay questions are biased downward due to response incentive effects.

In conclusion, we find that North Carolina residents state that they are willing to pay substantial amounts of money to maintain agricultural research and extension programs. Our methodological comparison raises an important concern. In this application follow-up willingness-to-pay questions are required to find divergent validity in willingness to pay for different government programs. However, follow-up willingness-to-pay questions may bias willingness-to-pay estimates downward. Future research should be conducted in which the differences in government programs are described more fully as in Smith. Perhaps then a finding of divergent validity would not come at the cost of potentially downward biased willingness-to-pay estimates.

References

Alberini, Anna. "Efficiency vs Bias of Willingness-to-Pay Estimates: Bivariate and Interval-Data Models." *Journal of Environmental Economics and Management* 29,2(1995):169–180.

Cameron, Trudy Ann. "Interval Estimates of Non-Market Resource Values from Referendum Contingent Valuation Surveys." *Land Economics* 67,4(1991):413–421.

Cameron, Trudy Ann, and Daniel D. Huppert. "OLS versus ML Estimation of Non-market Resource Values with Payment Card Interval Data." *Journal of Environmental Economics and Management* 17,3(1989):230–246.

Cameron, Trudy Ann, and Michelle D. James. "Efficient Estimation Methods for 'Closed-Ended' Contingent Valuation Surveys." *Review of Economics and Statistics* 68, 2(1987):269–276.

Cameron Trudy Ann and John Quiggin. "Estimation Using Contingent Valuation Data from a 'Dichotomous Choice with Follow-up' Questionnaire." *Journal of Environmental Economics and Management* 27,3(1994):218–234.

Carson, Richard T., Nicholas E. Flores, Kerry M. Martin, and Jennifer L. Wright. "Contingent Valuation and Revealed Preference Methodologies: Comparing the Estimates for Quasi-Public Goods." *Land Economics* 72,1(1996):113–128.

Carson, Richard T., Theodore Groves, and Mark J. Machina, "Incentive and Informational Properties of Preference Questions." Plenary Address, European Association of Environmental and Resource Economists, Oslo, Norway, June, 1999.

Greene, W. H. *Econometric Analysis*, Third Edition, Upper Saddle River, New Jersey: Prentice Hall, 1997.

Greene, W. H. *LIMDEP Version 7.0: User's Manual*, Bellport, New York: Econometric Software, 1998.

Haab, Timothy C. and Kenneth E. McConnell. "Referendum Models and Negative Willingness to Pay: Alternative Solutions." *Journal of Environmental Economics and Management* 32,2(1997):251–270.

Hanemann, Michael, John Loomis, and Barbara Kanninen. "Statistical Efficiency of Double Bounded Dichotomous Choice Contingent Valuation." *American Journal of Agricultural Economics* 73,4(1991):1255–1263.

Hoehn, John P. "Valuing the Multidimensional Impacts of Environmental Policy." *American Journal of Agricultural Economics* 73,2(1991): 289–299.

Huffman, Wallace E., and Richard E. Just. "Funding, Structure, and Management of Public Agricultural Research in the United States," *American Journal of Agricultural Economics* 76,4(1994):744–759.

Langford, Ian H., Ian J. Bateman, and Hugh D. Langford. "A Multilevel Modelling Approach to Triple-Bounded Dichotomous Choice Contingent Valuation." *Environmental and Resource Economics* 7,3(1996):197–211.

Mitchell, Robert Cameron, and Richard T. Carson. *Using Surveys to Value Public Goods: The Contingent Valuation Method.* Washington, DC: Resources for the Future, 1989.

North Carolina State Data Center. Office of State Planning, http://www.ospl.state.nc.us/sdn/, February 26, 1999.

Norton, George W., Joseph D. Coffey, and E. Berrier Frye. "Estimating Returns to Agricultural Research, Extension, and Teaching at the State Level." *Southern Journal of Agricultural Economics* 16,1(1984):121–128.

Norton, Virgil, Dale Colyer, Nancy Anders Norton, and Larry Davis-Swing. "Issues and Trends in Agricultural and Agricultural Economics Research Funding." *American Journal of Agricultural Economics* 77,5(1995):1337–1346.

Perry, Gregory M. "Research and Extension Expenditures Rising." *Choices* Second Quarter(2000):24–25.

Smith, V. Kerry. "Can Contingent Valuation Distinguish Economic Values for Different Public Goods." *Land Economics* 72,2(1996):139–151.

Snedecor, G. W. and W. G. Cochran. *Statistical Methods*. Seventh Edition, Ames, Iowa: Iowa State University Press, 1980.

Swallow, Stephen K. and Marisa Mazzotta. "Toward Assessing the Non-Market Benefits of Experiment Station Research: A Case Study of Public Preferences for AES Research in Rhode Island." Selected Paper, 1999 Annual Meeting of the American Agricultural Economics Association, Nashville, Tennessee, August 8–11.

Welsh, Michael P. and Gregory L. Poe. "Elicitation Effects in Contingent Valuation: Comparisons to a Multiple Bounded Discrete Choice Approach." *Journal of Environmental Economics and Management* 36,2(1998):170–185.