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Paired Stated Preference Methods for Valuing Management of White Pine Blister Rust: Order Effects and Outcome Uncertainty

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ABSTRACT

The literature on nonmarket valuation includes many examples of stated and revealed preference comparisons. However, comparisons within stated preference methods are sparse. Specifically, the literature provides few examples of pairing both a discrete choice experiment (CE) and a contingent valuation (CV) question within a single survey. This paper presents results of a nonmarket valuation study that employs both methods to elicit public preferences over uncertainty of outcomes and over management strategies. The two methods were employed to examine public support for the proactive management of the invasive pathogen, *Cronartium ribicola*, that causes the lethal disease white pine blister rust in high-elevation forests in North America. By addressing three related questions, this study finds the following main results: First, both methods suggest the importance of presenting outcome uncertainty to respondents. Second, the results provide no evidence that preferences

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vary over the means taken for pursuing the given ends, which in this case is long term forest health. Third, the paired inclusion of both methods results in order effects for CE results but not for CV results. Results and discussion provide insight into the most appropriate stated preference approach for informing different types of decisions about the efficient management of public lands.

Keywords: Contingent valuation, Choice experiment, Invasive species, Forest management

1 Introduction

Choice experiments (CEs) and contingent valuation (CV) are the two main stated preference methods for nonmarket valuation (Champ *et al.*, 2017; Johnston *et al.*, 2017). While both CEs and CV can be structured to ask precisely the same questions about preferences, the two methods are well positioned to ask different but complementary questions. CV provides values for a good, policy, or program. In contrast, CEs provide values for the attributes that comprise a good, policy, or program. CV is better suited for understanding public preferences for the entirety of a well-defined program, whereas CEs can provide "values for changes in a single characteristic or values for changes in levels of characteristics or values for multiple changes in characteristics . . . " (Holmes *et al.*, 2017). These values can be used to provide insight into *how* to develop a program based on public preferences. However, compared to CV, CEs are more cognitively burdensome. Overall, neither method strictly dominates the other; as Johnston *et al.* (2017) recommend, "[t]he use of CV or a CE to describe the change being valued should be based on how respondents tend to perceive the good, the study objectives, and the information content of valuation scenarios." (p. 333)

The present study asks two different, but closely related, applied questions relevant to the management of high elevation forests for the disease white pine blister rust (WPBR), which is caused by the non-native pathogen *Cronartium ribicola*. The CV question asks about the overall value of a national-level program and its success in securing the long-term sustainability of the associated species, whereas the CE questions seek estimates of marginal values to support development of efficient management plans and actions. While general nonmarket benefits from forests are well documented (Barrio and Loureiro, 2010), fewer studies investigate the nonmarket benefits from managing invasive species in forests (Holmes *et al.*, 2008; Kramer *et al.*, 2003; Rosenberger and Smith, 1997; Rosenberger *et al.*, 2012).

A rich literature assesses the convergent validity of CEs and CV by comparing estimated results from the two. The typical approach in this literature involves implementing the two methods with similar attributes in a split-sample design, with the CE administered to one sample and the CV to the other. Some studies using this approach found no significant differences between the CE and CV values, including in the contexts of solid waste management decisions (Jin *et al.*, 2006), beach quality improvements (Loomis and Santiago, 2013), land-use management preferences (Dachary-Bernard and Rambonilaza, 2012), and wetland ecosystem service valuations (He *et al.*, 2016). Other studies found significant differences between CE and CV values between the split samples. Petrolia *et al.* (2014) used a split sample to compare a CE with a "binary choice" CE, functionally equivalent to CV, for valuing restoration of coastal wetlands, and found substantially higher values in the single referendum-style (i.e., CV) choice. Neher *et al.* (2018) compared CE and CV values for white water boating in the Grand Canyon at different hypothetical flow levels and found a difference in values for one of four flow levels, suggesting that the difference could result from either a lack of familiarity with that case or from the functional forms used for estimation. The present study extends the literature not by directly investigating comparability of results, but rather by investigating how the nature of the good, policy, or program being valued and the presence of the other stated preference question in the survey relate to the CE and CV responses.

Specifically, the present study differs from the typical study in the literature in that (a) its CE and CV questions are not directly comparable, yet (b) all respondents faced both types of questions but with the order of the two sets of questions randomized in a split sample approach. We examine three questions. RQ1: How does the stated uncertainty of management outcomes affect results from both methods? RQ2: Do preferences vary over the means taken for pursuing the given ends, which in this case is long term forest health? RQ3: Does the paired inclusion of both methods influence responses?

2 Background

Though non-native forest pests and diseases are well recognized to be a substantial threat to biodiversity and ecosystem services worldwide, rigorous understanding of the economic and nonmarket effects of many of these invasions remains elusive (Boyd *et al.*, 2013; Lovett *et al.*, 2016; Aukema *et al.*, 2011; Holmes *et al.*, 2009; Born *et al.*, 2005). There is sparse understanding of the nonmarket values associated with limiting the spread of invasive forests disease. Among the few related studies, Drake and Jones (2017) use CV to elicit public willingness to pay (WTP) to protect against two specific forest diseases in England and Wales, and Sheremet *et al.* (2017) use a CE to find significant public benefits to addressing invasive plant diseases more generally in the UK. The present study expands on the analysis of CV data for the context of managing WPBR in high elevation, five-needled pine forests that was previously reported by Meldrum *et al.* (2011, 2013) and Meldrum (2015). It also builds on the findings of Naughton *et al.* (2019), who use a separate CV study to estimate willingness to pay for managing whitebark pine, one of the species threatened by WPBR, against multiple threats.

The present survey pairs CV questions aimed at eliciting public preferences for a national-level program to address this invasive species with CE questions aimed at eliciting public preferences relevant to the optimization of landscape-level management plans. One applied question concerns whether public preferences for WPBR management are affected by the specific types of management actions taken. Although the pathogen's complex lifecycle makes either eradication or containment of the disease unlikely, promising interventions such as prescribed burning, mechanical thinning, and planting genetically-resistant five-needled pine seedlings exploit the natural resistance of some trees to rust to improve these forests' resilience to the disease (Schoettle *et al.*, 2018; Jacobi *et al.*, 2017; Schoettle *et al.*, 2014; Burns *et al.*, 2008; Schoettle and Sniezko, 2007; Samman *et al.*, 2003). Previous CE research in other contexts has found mixed results on whether program attributes matter to study participants independently from primary outcomes. For example, Rolfe and Windle (2013) and Rogers (2013) found evidence that preferences over conservation outcomes for marine parks in Australia were influenced by CE attributes describing the management processes used to achieve those outcomes, whereas McVittie and Moran (2010) found respondents indifferent among different levels of restrictions in marine conservation zones, holding conservation outcomes constant. Johnston *et al.* (2012) found higher value estimates for indirect effects from restoration projects (e.g., fish-dependent wildlife species survival) *versus* direct effects (e.g., increases in the long-run probability of fish run survival). Closer to the present context, Rossi *et al.* (2011) found a preference for replanting over prescribed burning as a policy for southern pine beetle prevention on private forests, and Sheremet *et al.* (2017) found that WTP for forest disease control depends on the control methods used, with lower support for clear felling and chemicals than for thinning.

To the authors' knowledge, the literature has yet to implement a paired stated preference approach to investigate how uncertainty related to management outcomes and differing means to the same ends affect the results from the two valuation approaches. The few examples of paired CE and CV questions within the same survey tend to be structured so that results are directly comparable. Adamowicz *et al.* (1998) estimated separate and joint models of CV and CE data and found favorable properties from the CE model and either somewhat lower or somewhat higher welfare measures from CE, depending on assumptions. Hynes *et al.* (2011) compared CV results with those from a set of CE questions asked later in the survey and found no statistically significant differences between the CV and CE responses. While these examples do not consider potential order effects from the multiple question types, Johnston *et al.* (2017) suggested that survey design with multiple valuation questions must consider the impacts of their sequencing. For example, Day and Prades (2010) and Day *et al.* (2012) demonstrated implications of ordering in the sequence of multiple CE questions, and numerous theories from behavioral economics predict that the order of different questions can influence responses more generally (Alevy *et al.*, 2011; Carlsson, 2010). In the present study, the pairing of the two methods allows investigation of not only the relationship of estimated results, but also how the two instruments might interact.

Complex ecological processes associated with many management interventions result in uncertain outcomes. Management interventions for WPBR in high-elevation forests fall squarely into this category. The long generation time of the five-needled pine species that are threatened by WPBR means the long-run effectiveness of any management plan is uncertain (Burns *et al.*, 2008; Samman *et al.*, 2003; Schoettle and Sniezko, 2007; Field *et al.*, 2012). Thus, this study also focuses on the implication of explicitly addressing uncertainty of management outcomes within both the CE and CV designs. That is, it focuses on uncertainty not over whether the plan is implemented but rather whether it is successful. Johnston *et al.* (2017) pointed out that the literature increasingly demonstrates the importance of addressing risk and uncertainty in program outcomes. For example, Roberts *et al.* (2008) found substantially higher WTP to avoid algae blooms and maintain normal water levels when they presented CE choices with uncertainty *versus* with certainty. They suggest multiple possible reasons for this counterintuitive result, including that the stated end-state uncertainty "promotes a more realistic choice . . . and may thereby better approximate choice behavior in real situations," that "when the choice question is more complex, consumers more critically evaluate the tradeoffs between the attributes that vary among the options," or that perhaps respondents "may respond to the [certain] choice questions by assigning subjective probabilities to the outcomes in the experiment" (p. 592). Wielgus *et al.* (2009) found that model fit improved when they explicitly stated a high outcome probability *versus* when they provided no information on outcome uncertainty, and Cameron *et al.* (2011) described "scenario adjustment" as the effect when participants may accept a scenario described by a stated preference question yet "'adjust' some of its informational aspects to fit their own personal situation, history or context" (p. 10), as Flores and Strong (2007) found for CV choices, which can be influenced by subjective beliefs about project costs. Similarly, Provencher *et al.* (2012) conducted a CV study on Eurasian Watermilfoil (*Myriophyllum spicatum*) invasions that affect lake quality and demonstrated the importance of accounting for subjective expectations in the baseline scenario. Accordingly, a growing number of studies address outcome uncertainty, either by including uncertainty over the entire set of non-cost attributes in a choice (e.g., Rolfe and Windle, 2015; Wielgus *et al.*, 2009), which corresponds to collinear uncertainty for different outcome characteristics, or by including uncertainty as an individual attribute (e.g., Glenk and Colombo, 2011; Rigby *et al.*, 2010; Veronesi *et al.*, 2014), which is more appropriate when not all attributes (e.g. thinning or burning current acreage) are uncertain. Other studies (Bartczak and Meyerhoff, 2013; Lew *et al.*, 2010) have found that CE estimates of WTP under uncertainty depend on the "baseline" chance of the outcome. However, most of the above examples are CE studies; to date, outcome uncertainty in CV studies remains relatively uncommon. Closest analogs tend to appear in the literatures on respondent uncertainty (e.g., Hanley *et al.*, 2009; Ready *et al.*, 2010), which model respondents' uncertainty in their own responses, and on payment and provision uncertainty, which relate to the uncertainty of the chosen option being implemented and/or respondents being compelled to make payment (e.g., Champ *et al.*, 2002; Christantoni and Damigos, 2018; Mitani and Flores, 2014; Poe *et al.*, 2002).

3 Survey and Methods

Survey data were collected as part of a broader project on the costs and benefits of managing WPBR in high-elevation forests. As described in more detail elsewhere (Meldrum *et al.*, 2011, 2013; Meldrum, 2015), the survey instrument was developed through a series of focus groups, a pretest, and extensive consultation with natural scientists, closely following recommendations of Champ *et al.* (2003). Knowledge Networks, Inc.[1] administered the online survey to a probability-based sample of the general population in the western United States in June of 2010. Over a period of 11 days, 541 of 895 contacted individuals completed the survey, for a completion rate of 60%. Probability weights, based on the inverse probability of selection from the population and correcting for oversampling of the Mountain region to ensure adequate coverage, were provided by Knowledge Networks, Inc. and used for all reported estimates. See Table 1 for demographics of raw sample, weighted sample, and study population; more details are provided elsewhere (Meldrum *et al.*, 2011, 2013; Meldrum, 2015).

In the analyzed sample, the average respondent was 49 years old, and 53% were women. One in the three respondents (32%) had earned a bachelor degree, 75% were white, non-Hispanic, and the median reported income was between \$50,000 and \$59,999. On a five-point scale ranging from strongly disagree (1) to strongly agree (5), 75% of respondents agreed (4 or 5) with the statement

[1] Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Table 1: Demographics of raw sample, weighted sample, and study population.

Variable	Raw Sample	Weighted Sample	Population[a]
Census division			
Mountain (MT, ID, WY, CO, NM, AZ, UT, NV)	71%	32%	34%
Pacific (WA, OR, CA)	29%	68%	66%
Gender			
Male	47%	49%	50%
Female	53%	51%	50%
Age			
18-29	16%	23%	24%
30-44	22%	28%	28%
45-59	30%	26%	27%
60+	31%	22%	22%
Educational Attainment			
Less than High School	10%	15%	16%
High School	23%	25%	27%
Some College	35%	31%	31%
Bachelor and beyond	32%	29%	26%
Race/Ethnicity			
White, Non-Hispanic	75%	59%	55%
Black, Non-Hispanic	2%	2%	5%
Other, Non-Hispanic	6%	10%	10%
Hispanic	14%	25%	29%
2+ Races, Non-Hispanic	2%	4%	2%
Other Criteria			
In a Metropolitan Statistical Area	86%	91%	91%
Number of Respondents/Housing Units	*541*	*541*	*27,115,377*

[a]Statistics derived from U.S. Census Bureau, Current Population Survey, 2007, U.S. Census Bureau, Population Estimates Program, 2009, and 2006–2008 American Community Survey 3-Year Estimates.

that "protecting five-needled pines from the threat of extinction is important" whereas only 16% agreed that "people should not intervene in high-elevation forests." Although only 31% agreed that "tourism related to high-elevation forests is important," more than half (63%) have visited at least one of three major National Parks (Rocky Mountain, Yellowstone, and Glacier) in the range of the high-elevation white pines, and 75% expect to visit at least one of those parks in the future. At the time of publication, data are not available from Colorado State University but will be made available upon request to the corresponding author.

3.1 Experimental Design

The survey implemented a split sample design to randomize the order of the CV and CE questions within the survey. After introductory material and general questions about familiarity and experience with high-elevation white pine forests, half of the sample faced two CV questions followed by a series of six CE choice sets, whereas the other half faced the six CE choice sets followed by the two CV questions. Both groups were informed of the total number of questions and the two types of questions prior to being asked to complete the CE or CV questions. The online survey format assures adherence to the intended survey order, because the entire survey could not be previewed, and previous answers could not be revisited after viewing following questions.

The CV experiment consisted of two questions, both of which asked about a "national-level program that might be used to managed all of the high-elevation forests in the Western United States": one without mention of outcome uncertainty, and a second with explicit inclusion of a projected outcome uncertainty level. Specifically, question 1 (Q1) asked:

> *Suppose managers treat [QUANT]% of the high-elevation forests in the Western United States. As a result, these acres will be healthy in 100 years from now. The remainder of the acreage would not be treated. Would your household be willing to pay a one time cost of $[BID1] to fund this program?*

and question 2 (Q2) asked:

> *Now suppose the managers treat [QUANT]% of the high-elevation forests in the Western United States, and as a result of these actions, there is a [UNCRT]% chance that these acres will be healthy in 100 years from now. The remainder of the acreage would not be treated. Would your household be willing to pay a one time cost of $[BID2] to fund this program?*

where the variables (BID1, QUANT, and UNCRT) were randomly selected from the set shown in Table 2, and BID2 was randomly selected if the response to Q1 = "yes" and randomly selected such that BID2 $<$ BID1 if the response to Q1 = "no." Note that this constraint introduces a potential downward bias if the Roberts *et al.* (2008) result of stated uncertainty leading to higher estimated values holds. However, whereas the Roberts *et al.* result was obtained from a split sample, the present design of consecutive questions required the constraint to avoid a strictly dominated sequence of questioning in which a "no" response

Table 2: Contingent Valuation (CV) Design.

Contingent Valuation (CV) Design		
	Question 1	Question 2
Cost of program (BID)	\$10, \$25, \$50, \$100, \$250, \$500, \$1000	\$1, \$10, \$25, \$50, \$100, \$250, \$500, \$1000
Portion of forest (QUANT)	30%, 50%, 70%	30%, 50%, 70%
Chance healthy (UNCRT)	100% (implicit)	40%, 65%, 90%

to BID1 is followed by a BID2 > BID1, paired with a lesser (in terms of a lower chance of long term healthy) but more expensive program. Sensitivity to this potential bias is investigated below by splitting results to Q2 by response to Q1.

The CE asked respondents to make tradeoffs among long term effectiveness, costs, and short-term attributes of different management plans in an unnamed 1000-acre forest located on public land in the mountains of central Colorado. Figure 1 depicts the format of the CE questions. There were two versions of the CE, based on whether the top panel described the unnamed 1000-acre forest as having either a "high" or "low" overall current level of WPBR infection. The "high infection" version (Forest = 1) described a 1000-acre forest that had 750 acres with a high infection level, 150 acres with a moderate infection level, and 100 acres with a low infection level; the "low infection version" (Forest = 0) described a 1000-acre forest that had 750 acres with a low infection level, 150 acres with a moderate infection level, and 100 acres with a high infection level. These two versions were included to test whether preferences towards management and outcomes were dependent on the initial state of the forest; that is, do preferences for long-term outcomes (ends) depend on what type of forest is treated (means) (RQ2). Each respondent received only one of the two versions.

The lower panel of each CE question described three management options in terms of the attributes shown in Table 3. All attributes, levels, and choice descriptions were developed with extensive input from natural scientist experts on WPBR and high elevation forests and with insights gathered through general-public focus groups. Options were described by where treatment occurs (referring to the areas described in words and the pie chart in the top panel), the type of treatment that would be implemented (selective thinning, controlled burning, planting five-needled pine seedlings that are resistant to WPBR, or combinations thereof), the total one time household cost of the program (determined by multiplying one of three cost-per-acre values by the number of acres treated), and the chance that this 1000 acre high-elevation forest will be healthy, "defined as natural continuation of all four stages of the life cycle [depicted in Figure 2] (including forest regeneration) in 100 years".

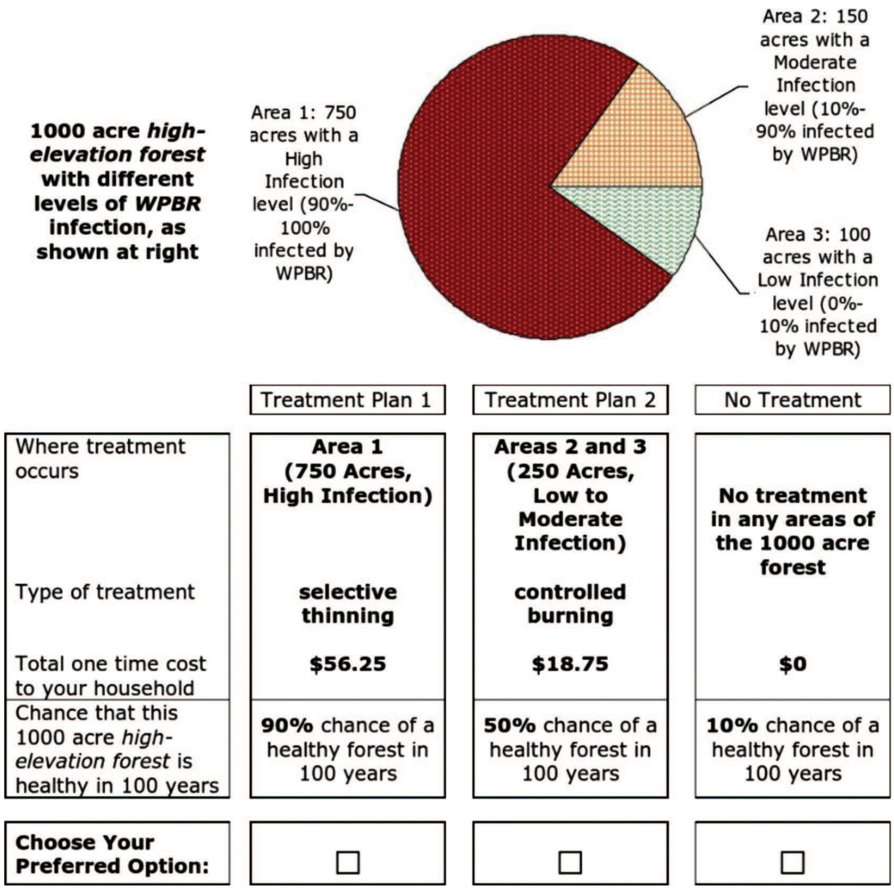

Figure 1: Example of a typical choice set.

The survey instrument (presented in the Online Appendix) also presents numerous other characteristics of a "healthy" forest, most notably in describing associated ecosystem services such habitat provision, soil protection, unique aesthetics, water provision, scientific value, and recreation opportunities.

In addition, each question contained a "no treatment" (status quo) plan in which no areas of the 1000 acre forest would be treated at a cost of $0, with an either 10% or 25% baseline chance of this forest being healthy in 100 years without treatment. The baseline chance was held constant for each respondent but varied independently of the "high infection" or "low infection" current forest condition (Status quo chance healthy = 0 if 10%, = 1 if 25%). This was done to test the sensitivity of the results to changes in threat level. Attribute levels were chosen using a fractional factorial design of six different

Table 3: Choice Experiment (CE) Design.

Choice Experiment (CE) Design		
	Status Quo	Alternatives
Cost per Acre	\$0	\$0.05, \$0.075, \$0.10
Acres treated	0	100, 250, 750, 900, 1000
Treatment type	n/a	Thin, Burn, Plant, Thin & Plant, Burn & Plant
Chance healthy	10%, 25%	50%, 70%, 90%

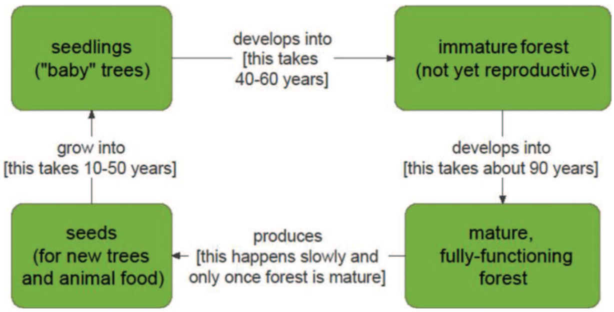

Figure 2: Schematic depicting life-cycle of five-needle pines in a healthy high-elevation forest.

blocks of six choice sets, selected to minimize the D-efficiency criteria (Lusk and Norwood, 2005).

To summarize, the study involved three treatments (Status quo chance of healthy, Forest, and Order), each of which was implemented via a split sample. As depicted in Figure 3, these three treatments address this study's three primary research questions. Split samples were balanced across treatments, with the three-way combination of treatments generating eight treatment groups of equal size. Further, RQ1 is also tested by the "chance healthy" variable within the second CV question and the "chance healthy" alternatives in the CE questions themselves, and RQ2 is tested by the "treatment type alternatives" within the CE questions.

3.2 Estimation

CV and CE data are modeled separately. CV results are estimated with a seemingly unrelated bivariate probit regression with Huber/White/sandwich estimator robust standard errors, as described in Greene (2012), with controls for order treatment effects. This approach models the likelihood of each response ($y_1 = 1$ if answer to Q1 = "yes", $y_1 = 0$ otherwise, and likewise for y_2

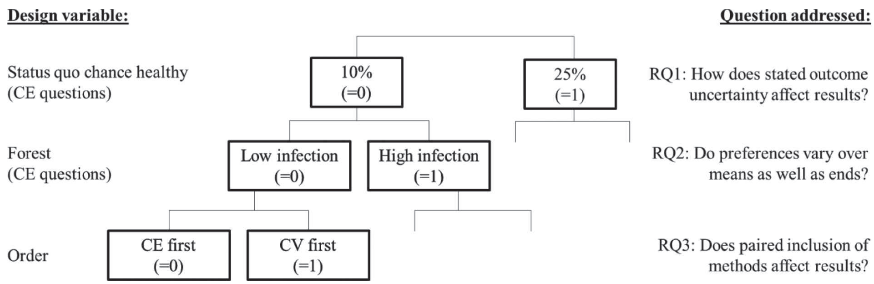

Figure 3: Schematic depicting treatment-level research design.

and Q2) as a probit regression of indirect utility, assumed linear in parameters, with potentially correlated error terms between responses to Q1 and Q2. This approach contrasts with typical interval-based approaches to estimation of double-bounded dichotomous choice CV data (Hanemann *et al.*, 1991), because the introduction of the uncertainty in the follow-up question potentially changes the hypothetical good, policy, or program being purchased in the question, but it follows other examples in the literature with two sequential CV questions (Kramer *et al.*, 2003). Mean WTP is estimated at the mean level of included covariates following Hanemann (1989), and confidence intervals for all WTP value estimates were estimated using the Krinsky and Robb (1986) simulation method with 50,000 replications. Note that this approach allows for negative WTP estimates, which could be observed if non-pecuniary costs of management, such as human interference in wilderness-like areas, are associated with greater disamenity than any benefits of treatment.

Following standard practice (Holmes *et al.*, 2017), CE responses are linked to the theoretical construct of utility using the conditional logit model in a random utility framework (McFadden, 1974), in which unobservable utility is the sum of observable, indirect utility, linear in parameters, and a random error component with an extreme value type I (Gumbel) distribution. For modeling, "treatment types" are interacted with the number of acres treated, the number of "acres treated" are estimated as continuous variable, and the "total cost" is calculated by multiplying cost per acre by the number of acres treated. As described below, models are estimated with and without a constant term (constant = 1 if not status quo), and with and without controls for the three treatments. Given the known limitations of the conditional logit model, as well as the heterogeneity demonstrated in previous analyses of the first CV question, estimation of all models with a mixed logit specification (e.g., Revelt and Train, 1998) was explored but is not shown below, because estimated parameter standard deviations were nearly all insignificant, suggesting little improvement in explanatory value. Mean marginal WTP is estimated as the ratio of the relevant coefficient to the coefficient for total cost, with confidence intervals for all WTP value estimates estimated using the Krinsky and Robb (1986) simulation method with 50,000 replications. This again allows the possibility of negative WTP estimates.

4 Results

4.1 Contingent Valuation

Basic CV results and their heterogeneity have been investigated previously (Meldrum *et al.*, 2011, 2013; Meldrum, 2015). This analysis focuses instead on introducing the second CV question, which explicitly describes outcome uncertainty (RQ1), and investigating the potential for order effects between the CE and CV experiments through the "order" treatment control variable (RQ3). Main results are shown in Table 4 below. The first column presents results for a standard probit model of Q1, which ignores uncertainty, and the second column presents results for the bivariate probit model of both Q1 and Q2.

Estimated results are consistent for Q1 across the first two columns, and ρ is positive and significant for the bivariate probit, demonstrating a strong correlation in response across the two questions. Despite previous analyses teasing out substantial insight from modeling of Q1 alone, Q2, which makes uncertainty explicit, produces much more nuanced results, suggesting that respondents attended more fully to the details of the question when presented with the more realistic outcome-uncertain scenario. While basic cost sensitivity (i.e. a negative and significant response to the cost of the program) is robust across questions, a positive response to increasing the portion of forest treated and chance of long-run forest health is only demonstrated in Q2. This result is consistent with Roberts *et al.*'s (2008) suggestion that their similar results stem from respondents more critically evaluating tradeoffs when a choice question is made more complex by including end-state uncertainty. The insignificant coefficients on the Order indicator variable suggest no observable order effects in the CV question from respondents who faced the CE questions before the CV questions. Finally, to investigate the potential bias from constraining BID2 $<$ BID1 when Q1 = "no," the third and fourth columns of Table 4 present results for a standard probit model of Q2 for the sub-sample answering "yes" or "no" to Q1, respectively. The final column depicts a strong negative cost sensitivity, and no sensitivity to the chance of a healthy forest, among the "no" group, suggesting that a presence of higher BID2 values would only increase the negative response, and thus that results here do not appear biased by this constraint.

Table 5 presents estimates of the WTP for the national level program, as well as the marginal WTP for attributes included in the questions. Overall WTP

Table 4: Results for standard and bivariate probit models of contingent valuation (CV) responses ($n = 541$).

	Standard Probit		Bivariate Probit		(If Q1 = "yes") Standard Probit		(If Q1 = "no") Standard Probit	
	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.
Q1: No mention of uncertainty								
Cost of program ($100)	−0.244***	0.032	−0.246***	0.031	[omitted]		[omitted]	
Portion of forest (10%)	0.042	0.064	0.040	0.063	[omitted]		[omitted]	
Order (=1 if CVM first)	−0.253	0.194	−0.225	0.193	[omitted]		[omitted]	
Constant	0.365	0.337	0.368	0.331	[omitted]		[omitted]	
Q2: Uncertainty explicit								
Cost of program ($100)	[omitted]		−0.291***	0.043	−0.294***	0.052	−0.856***	0.254
Portion of forest (10%)	[omitted]		0.116**	0.057	0.035	0.083	0.142*	0.078
Chance healthy (%)	[omitted]		0.011***	0.004	0.025***	0.006	0.000	0.006
Order (=1 if CVM first)	[omitted]		−0.085	0.182	0.108	0.272	−0.163	0.245
Constant	[omitted]		−0.738*	0.408	−0.767	0.620	−0.234	0.595
ρ	[omitted]		0.649***	0.092	[omitted]		[omitted]	
n	541		541		262		279	
McFadden's R^2	0.187		0.188		0.320		0.109	

Note: Coef. = coefficient; S.E. = standard error (robust); *p <0.10, **p <0.05, ***p <0.01; WTP for Bivariate Probit corresponds to Q2.

Table 5: Estimated willingness to pay (WTP) from contingent valuation (CV) data.

Estimated Willingness to Pay	Mean	S.E.	95% interval Low	High	Range
CV Q1 (standard probit)	\$183.66	\$39.92	\$99.70	\$259.19	\$159.49
CV Q1 (bivariate probit)	\$184.44	\$38.94	\$105.37	\$260.21	\$154.84
CV Q2 (from bivariate probit)	\$182.83	\$32.70	\$121.58	\$256.06	\$134.48
CV Q1: (marginal) per portion forest	\$1.61	\$2.58	−\$2.74	\$5.97	\$8.71
CV Q2: (marginal) per portion forest	\$4.00	\$2.01	\$0.78	\$7.61	\$6.83
CV Q2: (marginal) per chance healthy	\$3.92	\$1.36	\$1.76	\$6.42	\$4.66

Note: Krinsky-Robb confidence intervals; non-marginal estimates evaluated at relevant variable means.

results are quite stable across questions at approximately \$180 per household, although WTP is more precisely estimated from Q2, with a 95% interval range of \$135 *versus* \$155 or \$160 for Q1. These results are consistent with related studies, including Naughton *et al.* (2019), who also discuss numerous plausible reasons for them estimating a somewhat lower overall WTP of between \$86 and \$181 per household (95% interval; with mean at \$135). Although imprecisely estimated, results show a positive marginal WTP for an increasing portion of the forest treated, which is consistent with Kramer *et al.* (2003), who use a bivariate probit to estimate a sequence of CV questions designed to estimate marginal WTP to protect spruce-fir forests in the southeastern U.S. Results also show a positive but imprecise marginal WTP for the long-run chance of a healthy forest. Further investigation (not shown) finds no evidence of interaction effects between question order and the uncertainty attribute.

Interestingly, *post-hoc* math based on mean attribute levels suggests that Q1 is treated similarly to an inherent 65% chance of long-run health, on average, despite no explicit mention of uncertainty in this question. Assuming linearity in response to the chance of a healthy forest implies that 99% chance of long-run health is valued almost 75% higher, at \$318 per respondent.

4.2 Choice Experiment

CE results are displayed in Table 6. Comparing "first choice only" (columns 2 and 4) with "all 6 choices" (columns 1 and 3) suggests substantial cognitive burden from repeated choices, as responses became less systematic over the six choice occasions with similar patterns of coefficients for most variables

Table 6: Results for conditional logit models of choice experiment (CE) responses ($n = 541$).

	All 6 Choices		First Choice Only		All 6 Choices		First Choice Only	
	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.
Total cost	−0.504	0.416	−1.927**	0.960	−0.881**	0.402	−2.246***	0.865
Acres	0.029	0.034	0.160**	0.073	0.064*	0.034	0.192***	0.072
Thin*Acres	−0.004	0.020	−0.032	0.045	−0.016	0.020	−0.039	0.045
Plant*Acres	[omitted]		[omitted]		[omitted]		[omitted]	
Burn*Acres	0.023	0.023	0.033	0.056	0.004	0.023	0.020	0.055
Thin & Plant*Acres	−0.004	0.022	−0.013	0.050	−0.021	0.022	−0.028	0.051
Burn & Plant*Acres	−0.005	0.022	−0.003	0.047	−0.007	0.021	−0.004	0.049
Chance healthy (%)	−0.001	0.003	−0.001	0.007	0.013***	0.002	0.012**	0.005
Order (=1 if CV first)	−1.147***	0.334	−1.005**	0.450	[omitted]		[omitted]	
Forest (=1 if high infection)	−0.080	0.355	−0.391	0.419	[omitted]		[omitted]	
Status quo chance healthy (=0 if 10%, =1 if 25%)	−1.053***	0.355	−1.119**	0.488	[omitted]		[omitted]	
Constant (1=not status quo)	2.201***	0.444	2.271***	0.617	[omitted]		[omitted]	
Wald χ^2 (df)	19.69 (10)		19.20 (10)		54.63 (7)		33.02 (7)	
p-value	0.032		0.038		<0.001		<0.001	

Note: Coef. = coefficient; S.E. = standard error (clustered by respondent); *p <0.10, **p <0.05, ***p <0.01.

but smaller effects and larger standard errors from all 6 choices. Thus, both sets of results are presented. The first two columns of Table 6 demonstrate a positive alternative specific constant (ASC) associated with the non-status quo options, implying a preference for action; this demonstrates respondents tend to opt in to the CE questions, all else equal – but were less likely to do so if they already answered the CV questions, or if they were presented with the higher Status quo chance of healthy. The former could be explained perhaps by respondents already having expressed their preference for action in the CV response, whereas the latter is consistent with respondents feeling action is less urgent with the healthier status quo forest. However, other than as a check for status-quo bias which is not observed here, the ASC is challenging to interpret, as it represents taking action yet holding all other attributes (acres treated, chance of healthy, and management actions) constant.

Investigation of significant coefficients suggests that respondents are generally responsive to cost, but more likely to choose plans with more acreage and with a higher long-run chance of a healthy forest. In contrast, there is no evidence that respondents have preferences over "how" the management occurs; that is, the management actions burn, plant, thin, or a combination thereof, are irrelevant. This lack of preference over management actions, which addresses research question (2), remains supported through investigation, not shown, with interactions with split sample indicators and with a mixed logit specification, for which the only difference is that "Thin" coefficients have significant and large standard deviations.

Next, Table 7 depicts the three significant choice attributes and interactions with the two significant indicators for split sample designs. Consistent with above, both interaction effects are stronger for the first choice only (columns 2 and 4) than for all 6 choices (columns 1 and 3). For the former, facing the CV first (research question 3) or a higher status quo chance of a healthy forest (research question 1) reduced cost sensitivity. Other interactions results are not particularly robust across the full or first choice set only, but results overall are consistent with a reduced sensitivity to attributes, whether the size of the area treated or the long-run chance of a healthy forest, associated either with facing the CV questions before the CE questions or with a higher status quo chance of long-run forest health.

Finally, Table 8 depicts WTP estimates from the CE data, with explicit exploration of the potential for question order effects, for further exploration of RQ3. Overall, results demonstrate a positive WTP for taking action, with treating all 1000 acres valued at approximately \$60 per household, with a 95% confidence interval between \$7 and \$101, for the full 6 choices and ignoring order effects. Although direct comparison is not possible, this is consistent with the diminishing returns and an approximately \$180 estimate from CV, which asks about a program to manage for WPBR in "all high-elevation forests" in the western US, a much larger scale program.

Table 7: Results for conditional logit models of choice experiment (CE) responses, interaction terms.

	All 6 Choices		First Choice Only		All 6 Choices		First Choice Only	
	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.
Total cost	−1.221**	0.578	−3.872***	1.408	−1.250**	0.590	−3.640***	1.302
Total cost * Interaction	0.603	0.752	3.052*	1.699	1.010	0.717	3.217*	1.682
Acres	0.100**	0.050	0.343***	0.102	0.107**	0.052	0.258***	0.096
Acres * Interaction	−0.087	0.066	−0.310**	0.124	−0.109*	0.061	−0.172	0.122
Chance healthy (%)	0.018***	0.003	0.015**	0.006	0.014***	0.003	0.020***	0.006
Chance healthy * Interaction	−0.009*	0.004	−0.005	0.009	−0.005	0.005	−0.023**	0.010
Interaction variable	Order		Order		Status quo chance		Status quo chance	
Wald χ^2 (df)	22.73 (7)		19.20 (7)		21.97 (7)		23.14 (7)	
p-value	0.002		0.006		0.003		0.002	

Note: Coef. = coefficient; S.E. = standard error (clustered by respondent); *p <0.10, **p <0.05, ***p <0.01.

Table 8: Estimated willingness to pay (WTP) from choice experiment (CE) data.

			95% interval		
Estimated Willingness to Pay	Mean	S.E.	Low	High	Range
All 6 CE choices:					
CE: (marginal) per acre forest	\$0.062	\$0.020	\$0.007	\$0.101	\$0.094
CE: (marginal) per acre forest (CE first)	\$0.082	\$0.017	\$0.043	\$0.126	\$0.083
CE: (marginal) per acre forest (CV first)	\$0.021	\$0.057	−\$0.232	\$0.247	\$0.479
CE: (marginal) per chance healthy (%)	\$0.015	\$0.007	\$0.008	\$0.048	\$0.040
CE: (marginal) per chance healthy (CE first)	\$0.015	\$0.008	\$0.007	\$0.052	\$0.046
CE: (marginal) per chance healthy (CV first)	\$0.015	\$0.013	−\$0.050	\$0.082	\$0.133
First CE choice only:					
CE: (marginal) per acre forest	\$0.081	\$0.018	\$0.053	\$0.130	\$0.077
CE: (marginal) per acre forest (CE first)	\$0.089	\$0.016	\$0.068	\$0.136	\$0.069
CE: (marginal) per acre forest (CV first)	\$0.041	\$0.061	−\$0.180	\$0.268	\$0.448
CE: (marginal) per chance healthy (%)	\$0.005	\$0.003	\$0.002	\$0.013	\$0.012
CE: (marginal) per chance healthy (CE first)	\$0.004	\$0.002	\$0.001	\$0.009	\$0.008
CE: (marginal) per chance healthy (CV first)	\$0.012	\$0.014	−\$0.040	\$0.057	\$0.096

Note: Results from simplified model omitting non-significant coefficients; Krinsky-Robb confidence intervals.

Consistent across the different iterations, CE estimates are substantially larger when respondents faced the CE first; mean WTP per acre is as much as 4 times larger for CE-first than CV-first. This could perhaps relate to respondents reacting to, or anchoring on, information presented in the CV question, especially since no analogous effect is observed for the Status quo chance of a healthy forest (not shown). In addition to the overall level, estimates are also substantially less precise for respondents facing the CV questions first. This could perhaps relate to cognitive burden of response, as the effect is stronger for the full set of choices than for the first CE choice only. Overall, results are fairly consistent between the full set of 6 choice equations and the set of data constrained to the first CE question only.

5 Discussion

The methodological experiment described above provides empirical insight into three related questions about the most appropriate stated preference approach for complex management decisions about environmental goods. First, regarding RQ1, results demonstrate the importance of presenting outcome uncertainty to respondents. CV results suggest that respondents attended to the task more closely when uncertainty was made explicit. This is consistent with Wielgus *et al.*'s (2009) findings of improved model fit with explicit presentation of outcome uncertainty and with an overcoming of the effect of "scenario adjustment" by respondents to their own subjective beliefs (Flores and Strong, 2007; Cameron *et al.*, 2011) on CV choices. In the CE, the effect of the status quo chance of long-run forest health similarly suggests attendance to the baseline uncertainty; that is, respondents who saw the more threatened forest (lower baseline chance of healthy) were more likely to "opt in," all else equal, consistent with a greater sense of urgency being associated with higher threat. Similarly, both experiments demonstrate a positive marginal WTP for increasing chance of long-run forest health, although dummy-variable analysis (not shown) suggests WTP increases at a decreasing rate over tested probabilities. Specifically, while indicator variables for UNCRT = 65% and UNCRT = 90% with UNCRT = 40% omitted are both separately significant (β (UNCRT65) = 0.436, $p = 0.03$; β (UNCRT90) = 0.484, $p = 0.01$), there exists no evidence for rejecting the null hypothesis that the indicator variables differ ($p = 0.82$). In fact, *post-hoc* analysis of the CV WTP estimates suggests that, in the absence of uncertainty information, respondents answered as if the long-run chance of forest health, with treatment, was approximately 65%, not 100% as may often be intended.

Regarding RQ2, in contrast, the results provide no evidence that how management will be conducted influences preferences over that management in this empirical application. CE results suggest ambivalence across whether management is implemented via burning, thinning, or planting. Similarly, a complication intended to investigate proactive *versus* reactive management (a question of strong applied interest) motivated the split sample design of facing a current "high infection" or "low infection" forest in the CE. However, this difference appears irrelevant for response. Respondents appeared to consider increasing number of acres in the CE equivalently without respect to whether those acres were described as currently having "low" or "high" infection levels. In other words, results are consistent with the perspective of one focus group participant who deferred to the experts to make the detailed decisions, stating "if we're going to do something to fight this, we need to do it wherever it needs to be." That is, in this case, the ends justify the means in the eyes of respondents.

Finally, regarding RQ3, the analysis demonstrates order effects for CE results but not for CV results. Responses to the CE questions following the CV questions were generally more dispersed than when they preceded the CV questions, which is consistent with perhaps the additional complexity of the CE task leading to greater influence from the concerns of behavioral economics such as anchoring, priming, or information effects (see Johnston *et al.*, 2017 for discussion). As an alternative explanation, perhaps the simplicity of the referendum format allows an easier mental "reset" when answering the CV following the CE questions. Another possibility is that the presentation of multiple decision-making scenarios could also lead to respondents viewing the results as less consequential and subsequently reducing incentive compatibility (see Johnston *et al.*, 2017 for discussion), however, the relative stability of the first *versus* all six CE choice occasions, and the irrelevance of order to CV results, limits this concern. Regardless, while the order effects are an important finding, additional research would be needed to pin down the underlying sources of these results, as discussed in previous research explicitly designed to test stated preference order effects (e.g., Day and Prades, 2010; Day *et al.*, 2012; Alevy *et al.*, 2011).

6 Conclusion

The complexity of this study was motivated by a strong applied interest in not only whether the public values intervening in high elevation forests to mitigate the threat from white pine blister rust, but also if the public has preferences over whether such intervention is proactive *versus* reactive (i.e., depends on current forest conditions). The evidence strongly suggests that the public does value such mitigation highly, consistent with general stated preference results establishing significant nonmarket benefits from protecting forest health (as reviewed Kramer *et al.*, 2003; Barrio and Loureiro, 2010), but also that the public is significantly less interested in the details of how such mitigation occurs than in how effective it is expected to be. In this application, public support seems equally strong for proactive and reactive approaches. Knowing this information can help empower managers of public lands to make decisions based on the important considerations of scientific knowledge and cost effectiveness.

This study also provides empirical insight into details of stated preference study design. The results regarding order effects between subsequently-asked CE and CV questions underscore a need for caution in constructing survey designs with multiple stated preference experiments, particularly as the complexity of those experiments increases. The finding of order effects for CE results but not for CV results begs for further research into the underlying explanation of these effects and whether they generalize to other contexts. Further, as reviewed above, previous CE research has found mixed results on whether program attributes matter to study participants independently from primary outcomes. This study provides another empirical example in which respondents appear ambivalent about the means through which preferred ends are achieved; future research into underlying mechanisms promises to be fertile. Finally, studies often ignore the uncertainty of the delivery of a management program or policy's expected outcomes. This uncertainty includes not only provision uncertainty, in which an individual's choice is probabilistically rather than deterministically related to whether a program is implemented, but also outcome uncertainty. That is, nearly all management programs and policies entail uncertainty in whether they can reach their intended goals. The results of this study suggest that respondents answer a question that ignores uncertainty as if it indeed contains significant levels of uncertainty – approximately 65% chance of the promised outcome in the present context. This underscores the importance of accounting for subjective uncertainty of the delivery of the promised outcome in stated preference study design, either by eliciting those subjective outcomes separately and adjusting for them, or by incorporating uncertainty directly into CV or CE questions.

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