CHAPTER 8

ESTIMATING THE ECONOMIC VALUE OF TREES AT RISK FROM A QUARANTINE DISEASE

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Abstract. The total economic value of tree species susceptible to *Phytophthora ramorum*, the causative agent of sudden oak death, was investigated in North Yorkshire. The results of a dichotomous-choice contingent-valuation study, using a 'follow-up' dichotomous-choice question, are presented. Two approaches were used in order to obtain the mean willingness to pay (WTP): a bivariate probit model that provides information about the crucial variables that affect the WTP, and the maximization of a log-likelihood function that accounts for a double-bounded bid. Previous studies suggest that the second approach produces more accurate estimates. Using both methods the mean WTP was estimated to be approximately £55 per annum per individual taxpayer over five years. This is similar to values placed by the public on trees susceptible to *P. ramorum* in California, USA.
Keywords: bivariate probit model; contingent valuation; double-bounded model; *Phytophthora ramorum*; sudden oak death; total economic value; willingness to pay

INTRODUCTION

When designing phytosanitary measures to protect plants, it is useful to know the value of the plants that are being protected. Unlike a conventional crop, the valuation of trees in the wider environment requires an understanding that they form part of the rural landscape and therefore represent a 'public good'. The total economic value of an environmental public good includes factors such as how it is used, e.g., for recreation; the public knowing that it exists and will continue to exist; the public's willingness to pay (WTP) for future availability of the resource; and their WTP to avoid an irreversible loss of the resource. There are a variety of techniques available to assess the economic value of environmental public goods (Freeman III 1993). However, few studies have ever quantitatively measured the value of environmental public goods that specific phytosanitary measures are designed to protect. The revised International Standards for Phytosanitary Measures, ISPM 11 (FAO 2003) recognizes that different methodologies can be used to value environmental goods and recognizes the distinction between use and non-use values.

A.G.J.M. Oude Lansink (ed.), New Approaches to the Economics of Plant Health, 119-130

However, there is little guidance provided on any specific methods available for those using ISPM 11 (Baker and MacLeod 2005).

Contingent valuation (CV) has become one of the most widely used techniques to value environmental public goods. CV refers to approaches based on surveying a sample of a population and applying econometric analysis to the data obtained from the survey to determine what value the population places, or what maximum amount it is WTP, for an environmental public good, or to prevent a specific change in an environmental quality such as loss of trees. Referendum-type questions, with a “yes” or “no” answer can also form part of CV studies with statistical efficiency obtained using a second, follow-up, referendum-type question (Hanemann et al. 1991). With regard to trees throughout the countryside, CV is an appropriate technique because it enables both use and existence values to be measured, which other techniques such as the travel cost method are not able to do. Bräuer (2003) provides an overview of CV for non-economists.

Phytophthora ramorum is a quarantine plant pathogen first identified in the UK in 2002 (Lane et al. 2003). It has been found to be widespread with a low incidence on a range of propagated hosts such as *Camellia, Rhododendron* and *Viburnum* (Sansford et al. 2003). A number of common tree species, such as American red oak (*Quercus rubra*), Douglas fir (*Pseudotsuga menziesii*), European beech (*Fagus sylvatica*), Lawson’s cypress (*Chamaecyparis lawsoniana*), Sitka spruce (*Picea sitchensis*) and sweet chestnut (*Castanea sativa*) are ‘more susceptible’ potential hosts. ‘Less susceptible’ potential hosts include English oak (*Quercus robur*) and *Q. petraea*, European birch (*Betula pubescens*), horse chestnut (*Aesculus hippocastanum*), sycamore (*Acer pseudoplatanus*), European alder (*Alnus glutinosa*) and yew (*Taxus baccata*).

This paper describes the use of contingent valuation to estimate the economic value that a sample of people in North Yorkshire, UK, place on trees that are susceptible to *P. ramorum*, the causal agent of the diseases commonly referred to as Sudden oak death, Ramorum shoot dieback and Ramorum leaf blight (Hansen et al. 2002).

METHODS

All staff from Central Science Laboratory (scientific and non-scientific) were invited to participate in a survey which was conducted in a lecture theatre where they were introduced to the subject of quarantine pests and diseases that could harm trees in the UK. Photographic images of trees, including oak species, in the English countryside were shown, e.g. Figure 1, followed by images from the USA of dead and dying trees infected with *P. ramorum*. Digitally manipulated images were presented showing views of the English countryside with dead and dying trees, supposed to be infected with *P. ramorum*. Although susceptibility to infection may not be a good indicator of potential tree mortality due to *P. ramorum*, we assumed that *P. ramorum* could kill the ‘more susceptible’ hosts and that infected or dead trees and susceptible trees close by were felled and removed from woodlands to control the spread of the disease. Thus images of the landscapes were presented with the trees digitally removed to simulate the landscape under a scenario where the disease management policy involved cutting and removing infected trees and susceptible trees close by, e.g. Figure 2. There then followed a questionnaire consisting of 22 socioeconomic questions. Respondents were reminded of the social benefits that trees provide. To inhibit respondents from overestimating their WTP (Arrow et al. 1993) they were reminded that other government environmental protection programmes would continue independently.

***Figure 1**. One of the images of the English countryside used in the study showing tree species susceptible to P. ramorum*

***Figure 2**. Digital manipulation of Plate 1 to illustrate how the landscape may alter if infected and susceptible trees close by were removed to prevent spread of P. ramorum (Trees have been digitally removed from a section of hedgerow in the middle of the left hand side of the view)*

The WTP question concerning how much extra tax the individual was willing to pay to protect trees susceptible to P. ramorum was “If there were a public referendum to decide whether a Government Prevention Programme to prevent Sudden oak death from spreading should be implemented, and it cost you £x per year in additional taxes for 5 years, would you vote in favour of it?” In any questionnaire, x was either £30, £50 or £70. These values were uniformly and randomly distributed across respondents. Those who answered that they would be willing to pay £x were then asked if they would pay £20 more, i.e. either £50, £70 or £90, respectively. Those who answered that they would not be willing to pay £x were asked if they would pay £20 less, i.e. either £10, £30 or £50, respectively. The options for the value of £x (the bid amounts) were based on an earlier trial at CSL designed to determine the approximate limits for £x. Double “yes” and double “no” responses were investigated further in order to find protest responses or altruistic motives in the WTP responses. A ‘warm glow’ effect appears when, in spite of gaining utility from increasing the public-good supply, respondents also gain utility from the act of giving and may be present in the majority of bids giving an overestimation of WTP (Andreoni 1989). Consequently, respondents were asked to explain why they answered "yes" or "no" twice. Reasons that provided evidence for protest or altruistic votes were excluded from determining the mean WTP. For instance, responses such as "I would get pleasure from knowing that I had contributed to a good cause" or "I am opposed to paying for more government programs" were considered not valid.

A probit model is a nonlinear model for estimating values with a binary dependent variable, e.g. the "yes" or "no" responses to the WTP question. We assumed that WTP is distributed in the population according to both a normal cumulative distribution function (cdf) when the bivariate probit model is used, and a logistic distribution function (ldf) when maximizing the double-bounded log-likelihood function. The standard normal cdf is very similar to the ldf and essentially provides identical results. These functions can only be distinguished in very large samples (Aldrich and Nelson 1984).

The probit model is applicable to CV studies with one dichotomous-choice question but by introducing a follow-up dichotomous-choice question, the statistical efficiency improves by the application of a bivariate probit model (Carson et al. 1986).

We adopted the bivariate approach proposed by Cameron and Quiggin (1994), where the two discrete-choice responses are simultaneously modelled as single-bounded, i.e. two correlated WTP equations with jointly distributed normal error terms. This model provides information on what variables are crucial for each of the responses to the WTP question. Moreover, mean WTP for the first and the second question can be calculated from the coefficients obtained from the model. Despite there not being a strong correlation between the two discrete responses in the dataset used, estimation of the mean WTP is feasible using the bivariate probit CV model since bivariate normal probability density functions allow for a zero and non-zero correlation (Cameron and Quiggin 1994). Therefore estimation of the coefficients can be done using a bivariate probit model that would include two related models:

$$Y*_1 = \alpha_1 + \beta_1 B_1 + \sum_{i=2}^{n} \beta_i x_i + \varepsilon_1 \tag{1a}$$

$$Y*_2 = \alpha_2 + \beta_1 B_2 \sum_{j=2}^{m} \beta_j x_j + \varepsilon_2 \tag{1b}$$

$$corr[\varepsilon_1, \varepsilon_2] = \rho$$

where Y_1 and Y_2 are the binary responses to the WTP questions; B_1 and B_2 are the bids in the first and second bid question; x_i represent socioeconomic variables and

α's and β's are the coefficients to be estimated. The explanatory variables of model 1 can be different from the explanatory variables of model 2.

Another way of estimating the parameters is by maximizing the following log-likelihood function:

$$\begin{aligned}
&\sum_j \sum_i I_{ji}^1 I_{ji}^2 \ln[1-\psi(f(B^u, x_{ji}))] + \\
&+\sum_j \sum_i I_{ji}^1 (1-I_{ji}^2) \ln[\psi(f(B^u, x_{ji})) - \psi(f(B, x_{ji}))] + \\
&+\sum_j \sum_i (1-I_{ji}^1)(1-I_{ji}^2) \ln[\psi(f(B^l, x_{ji}))] + \\
&+\sum_j \sum_i (1-I_{ji}^1) I_{ji}^2 \ln[\psi(f(B, x_{ji})) - \psi(f(B^l, x_{ji}))], \\
&i = 1..N,\ j = 1..M
\end{aligned} \tag{2}$$

where I_{ji}^1 indicates a first positive response and I_{ji}^2 indicates a second positive response; B^u and B^l are the upper and lower bid bounds; ψ is the distributed i.i.d. logistically, and f is a function that depends on the bid (B) and a set of socioeconomic variables (x). In respect to the variables included in this model only the first and second bid were included as explanatory variables. The mean WTP, which is shown in Table 5, is what in common usage would be termed the average WTP of the sample.

Whilst the bivariate probit model can be used to determine the mean WTP, previous studies suggest that maximization of a log-likelihood function that accounts for a double-bounded bid produces more accurate estimates of mean WTP. Hence such a technique was used to estimate an alternative mean WTP following Hanemann et al. (1991).

RESULTS

A total of 81 observations were collected. Eighteen (22.2%) were removed from further analysis since they indicated protest or altruistic votes and therefore were not truly valuing the plant protection programme[1]. Additionally, 22 respondents (27.2%) chose the “no answer” option given in the questionnaire[2]. These responses indicate that the 22 took the commitment to pay seriously. From those who responded “no”, 77% did not respond because they needed more information; 9% considered other problems are more important than *P. ramorum*; 9% responded by complaining about taxes being the method of payment; and 5% did not believe that trees would be killed by *P. ramorum* in the UK. In this respect, a higher rate of valid responses could be achieved by including more information about the disease and the protection programme. A total of 49.4% of observations was considered non-valid for the aim of valuing the plant protection programme. The probability of answering "yes" twice decreased when this bid amount increased. Conversely the probability of answering "no" twice increased when the bid amount increased (Table 1).

***Table 1**. Descriptive statistics (n=41)*

		Responses to the first/second bid [Y = Yes, N = No]			
Bid value thresholds (1st, 2nd)	*n*	Y/Y(%)	Y/N(%)	N/Y(%)	N/N(%)
£30 (50/10)	13	6 (46%)	4 (38%)	2 (15%)	0 (0%)
£50 (70/30)	12	4 (33%)	5 (42%)	2 (17%)	1 (8%)
£70 (90/50)	14	2 (14%)	6 (43%)	2 (14%)	4 (29%)

***Table 2**. Variable names used in bivariate probit models (see Table 3)*

Variable name	Meaning
BID 1	Amount of money asked in the first question
BID 2	Amount of money asked in the second question
MEMENV	Member of an environmental organization (YES=1)
GENDER	Female=1
AGE1829	Respondent's age is in the range of 18-29 year old
BAND	Respondent's staff grade at CSL (proxy variable for income)
DEPEND	Respondent's number of dependents
SODAW	Aware of *Phytophthora ramorum* in the UK
HIGH EDUCATION	First or higher degree

The variable names used in the model and their meanings are shown in Table 2. A total of 6 bivariate probit models were tested and compared in order to choose the best fit using the Log-likelihood test[3]. Table 3 shows the results for each model. Models 2, 4 and 6 are a variation of models 1, 3 and 5, respectively. The only difference is that variables BID1 and BID 2 are transformed to logarithms. Results show that this transformation does not improve the model results except for model 2 where the results are slightly improved and the standard error of the estimated mean WTP for the second question is smaller. Models 3 and 4 added gender and being a member of an environmental organization (GENDER and MEMENV) to the first equation and the proxy variable for salary (BAND) and dependent family members (DEPEND) to the second equation.

***Table 3**. Comparison of results of Bivariate probit models*

Parameter	Model 1	Model 2†	Model 3	Model 4†	Model 5	Model 6†
Equation 1						
Constant	1.92**	5.57**	2.59**	6.42**	3.03**	6.74*
	(0.75)	(2.48)	(0.80)	(3.06)	(1.22)	(3.54)
BID 1	-0.03**	-	-0.03*	-	-0.03*	-
	(0.01)	-	(0.02)	-	(0.02)	-
log(BID1)†	-	-1.29**	-	-1.42*	-	-1.37
	-	(0.63)	-	(0.84)	-	(0.9)
MEMENV	-	-	0.78	0.75	0.42	0.40
	-	-	(0.87)	(0.88)	(0.97)	(0.96)
GENDER	-	-	-1.08**	-1.06*	-1.17*	-1.16*
	-	-	(0.54)	(0.56)	(0.67)	(0.68)
AGE1829	-	-	-	-	0.86	0.87
	-	-	-	-	(0.75)	(0.76)
WTP	£72***	£74***	£81***	£93	£97***	£137
	(12.54)	(18.93)	(25.58)	(58.84)	(37.36)	(123.47)
C.I. (90%)	£56-88	£49-99	£48-114	-	£48-146	-
Equation 2						
Constant	3.17**	13.51**	1.40	11.02*	1.64	11.72*
	(1.43)	(5.70)	(1.56)	(6.32)	(1.63)	(6.46)
BID 2	-0.06**	-	-0.05**	-	-0.05**	-
	(0.02)	-	(0.03)	-	(0.03)	-
log(BID2)†	-	-3.38**	-	-3.13**	-	-3.30**
	-	(1.41)	-	(1.58)	-	(1.59)
BAND	-	-	0.55**	0.57**	0.55**	0.56**
	-	-	(0.24)	(0.24)	(0.24)	(0.25)
DEPEND	-	-	-0.42	-0.41	-0.44	-0.43
	-	-	(0.31)	(0.30)	(0.30)	(0.31)
WTP	£56***	£54***	£57***	£56***	£57***	£56***
	(3.92)	(3.62)	(5.22)	(4.78)	(5.11)	(4.81)
C.I. (90%)	£51-61	£49-59	£50-64	£49-62	£50-64	£50-62
log *L*	-43.49	-43.35	-34.93	-35.12	-33.69	-33.81
Wald Statistic	226.62	231.70	149.77	150.69	139.79	138.19
RHO (p-value)	0.40	0.26	0.52	0.63	0.67	0.74
Pseudo-R^2 statistic	0.14	0.15	0.31	0.31	0.34	0.33

* Significant at 10% ** Significant at 5% ***Significant at 1%

The addition of these variables improves the model significantly (see Log *L* and Pseudo-R^2)[3]. Therefore, the bivariate probit model 3 shows that including GENDER, MEMENV, BAND, and DEPEND in the model increase the model performance. The likelihood ratio was used to test the join significance[4] with the result of rejecting the null hypothesis of not-join significance of these four added variables (p-value < 0.01). GENDER and MEMENV are crucial in the first response although only GENDER is individually statistically significant. For the second response BAND and DEPEND are crucial although only BAND is statistically significant.

Despite adding AGE1829, models 5 and 6 slightly appear to improve the overall model results (see Log-*L*), the likelihood ratio statistic could not reject the null hypothesis of not-join significance. This result shows that adding AGE1829 to the model 3 does not improve it enough to include it (p-value>0.10). Moreover, estimates for the mean WTP become less reliable, especially for the first question.

Model 3 provides information about the behaviour of the variables. Thus, a significant negative relationship is found between BID1 and WTP (p-value <0.10) and between BID2 and WTP (p-value <0.05), i.e. the higher the tax the lower probability of answering yes to the WTP question. The fact that the coefficients for BID1 and BID2 are negative and BAND is positive, i.e. the higher the income the higher the probability of answering yes to the WTP question, validates the model in accordance with theoretical expectations. Figure 3 shows the proportion of respondents confirming that they would be willing to pay either of two amounts, the second amount being £20 higher than the first. As expected, the proportion willing to pay decreased as the bid amount increased. For those respondents not willing to pay the first bid, the proportion willing to pay a lower second bid increases as the first bid increases (Figure 4). In addition, gender was also found to be a statistically significant variable. Women are expected to be less WTP than men although no significant correlation between GENDER and BAND, the proxy for salary, was found. Despite neither MEMENV and DEPEND being individually significant, both were found to improve the overall model when included in the first and second equation, respectively. Estimates of WTP obtained from equation 1 are less significant than the estimates for equation 2. This is consistent with the Discovered

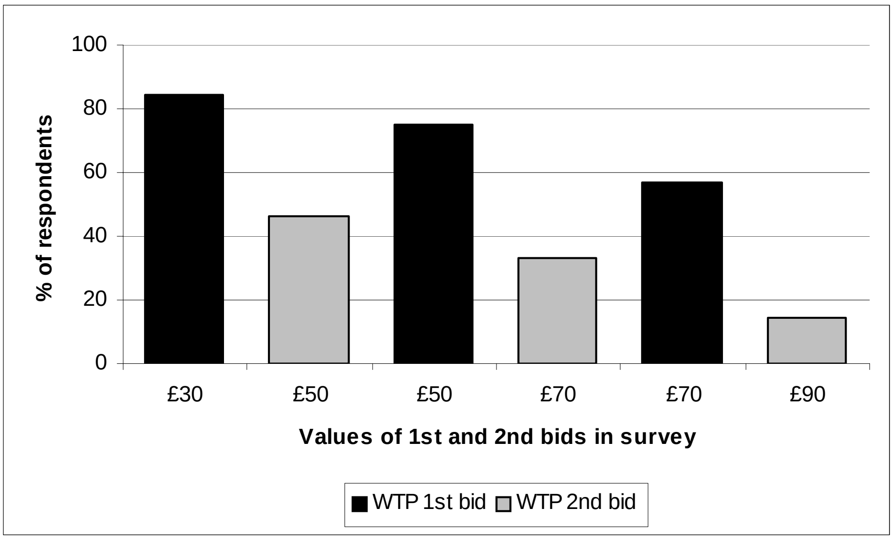

Figure 3. *The percentage of respondents willing to pay, both the first and second bid choice values (n= 41)*

Preference Hypothesis (DPH) proposed by Plott (1996), which points out that preference consistency is more likely to be observed after repeated valuation trials. Other variables were not included due to correlation problems. Thus, SODAW has been found to be positively correlated with BAND (p-value<0.01), which means that the higher the staff grade the more aware of the disease. Consequently, SODAW was not included in the model because of multicollinearity. BAND was also correlated with HIGH EDUCATION (i.e. first degree or higher degree) (p-value<0.05), which was expected.

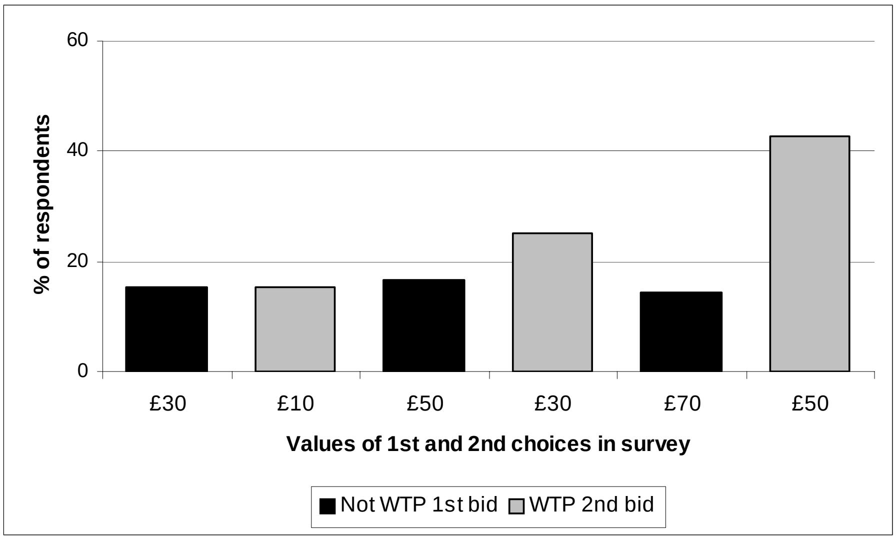

Figure 4. *The percentage of respondents not willing to pay, the first bid but willing to pay the second choice bid (n=41)*

Table 4 illustrates how average WTP is affected by variations in sociological factors such as gender and being a member of an environmental organization.

Table 4. *Comparison of significant groups' first bid Willingness To Pay using Model 3*

Sociological factor	mean WTP	Conf. Int. (90%)
Average	£81*** (25.58)	£48-114
Female	£47*** (10.49)	£33-61
Memenv	£105*** (28.39)	£68-142
Female and Memenv	£71*** (21.69)	£43-99

*Significant at 10% **Significant at 5% ***Significant at 1%

WTP was estimated using the bivariate probit model and the maximization of the double bounded log-likelihood function. Greater statistical significance was obtained using the second approach (Table 5). The mean WTP, which is shown in Table 5, is what in common usage would be termed the average WTP of the sample.

Table 5. *Willingness to pay – result from maximization of the double-bounded log-likelihood function.*

Variable	Mean Willingness to Pay	Conf. Int. (90%)
Sample population mean	£55***	£51-59

DISCUSSION

In the USA, Thompson et al. (2002) also used a double-bounded dichotomous-CV method and estimated that individuals placed a value of between \$75 and \$83 (approximately £43 and £47) on programmes to preserve oak woodlands in a particular Californian county. Such estimates are similar to our estimate of £55 for an individual's total economic value (TEV) of trees susceptible to *P. ramorum* in the UK. Multiplying up the public's individual mean WTP we have estimated that nationally susceptible trees may have a value of approximately £1.9 billion to the public. Scarpa (2003) collected primary data to augment data from 1992 and estimated the total recreational benefit (use value) of woodlands in the UK to be between £574 million and £962 million. His estimate did not consider non-use values and included all trees in woodlands, not just trees susceptible to *P. ramorum*; yet our estimate is significantly greater. This is probably because, by using CV, the present study includes non-use values, thus increasing the value of trees over their value when only use values are considered. Although the results for TEV may be overestimated due to a small sample population with higher average income than the UK average, and that 90.2% of the sample population were already aware of *P. ramorum*, it appears there is a significant TEV for trees susceptible to *P. ramorum* in the UK.

The relationship between WTP estimated from CV studies and actual observed behaviour has been empirically studied, and investigations have shown that CV performs reasonably well, with a level of accuracy consistent with other techniques used in economics (Cummings et al. 1986; Walsh et al. 1989). Nevertheless, a future wider study across the UK could be required to test the conclusions and WTP estimates obtained by this pilot study.

The model and the estimates of WTP obtained during this study provide crucial information for further research and especially for any future questionnaire design. In this respect, the questionnaire should examine causes of different WTP due to gender. This study showed that females are willing to pay less than males for plant protection programmes although there was no correlation between the salary proxy and gender. Future studies should sample from a larger population across a wide geographic population since it is reasonable to postulate that people from different regions may place different values on trees. The geographical distribution of the sample was not analysed due to the small size of the sample and especially to the constrained geographical location of the survey. The 'warm glow' effect and protest responses were found to be present in 19% and 5% of the entire sample, respectively. Consequently extra information related to the possible causes for altruistic preferences should be obtained in further studies. The protest responses were related to taxes being the method of payment. A higher rate of valid responses could be achieved by including more information about the disease and the protection programme, for example the questionnaire could indicate areas of the country with trees at most risk. Estimates of the mean WTP were found to be different between the first and the following-up question. The correlation coefficient Rho indicates that there was no strong correlation between the two discrete responses in the dataset used. The first question produced higher estimates of the mean WTP than the second question. An explanation for these results may be that respondents become more aware of the amount of money they have to pay when the question is asked a second time. This interpretation is based upon both income and number of repondent's dependents that are critical for the explanation of the response to the second question, i.e. respondents consider these variables when they are asked for the second time. This means that WTP estimates for the second question are preferred to the estimates for the first question. This is consistent with research on DPH, which argues that stable and theoretically consistent preferences typify a product of experience gained through practice and repetition (Plott 1996). Results of this study are also consistent with the literature of double-bounded being more efficient statistically than single-bounded (Cameron and Quiggin 1994).

ACKNOWLEDGEMENTS

We wish to thank CSL staff for taking part in this study; Garry Fry for digitally manipulating the images and Riccardo Scarpa for his advice and suggestions. This study was funded by CSL seedcorn project LB53 9002.

NOTES

[1] Follow up questions regarding possible reasons for unwillingness to pay as well as reasons for willingness to pay were included in the questionnaire to determine valid responses.

[2] Respondents were offered a 'no-answer' option as recommended in the literature (Arrow et al. 1993). This is expected to reduce problematic responses (i.e. answering "yes" or "no" without meaning it).

[3] Pseudo R^2 statistic is calculated as: $Pseudo-R^2 = 1 - \frac{LL_U}{LL_R}$ where LL_U represents the log-likelihood functions from the full model and LL_U the log-likelihood function for the restricted model.

[4] The likelihood ratio (*LR*) test is based on the same concept as the *F* test in the linear model. The *LR* test is based on the difference in the log-likelihood functions for the unrestricted and restricted models. The likelihood ratio statistic is twice the difference in the log-likelihood functions: $LR = 2(L_{UR} - L_R)$, where L_{UR} is the log-likelihood value for the unrestricted model and L_R is the log-likelihood value for the restricted model. The multiplication by two is needed so that *LR* has an approximated chi-squared distribution under the null hypothesis of not-join significance (Wooldridge 2000).

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