INVESTIGATING DISTANCE EFFECTS ON ENVIRONMENTAL VALUES.

A CHOICE MODELLING APPROACH

Giovanni B. Concu

Risk and Sustainable Management Group, University of Queensland (Australia)

DEIR, Universita' di Sassari (Italy)

Crenos (Italy)

Address for Correspondence:

School of Economics, University of Queensland

Brisbane, QLD, 4072 - Australia

tel +61 8 7 6635 6093

fax +61 7 3365 7299

e-mail: g.concu@uq.edu.au

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Abstract:

This paper describes a Choice Modelling experiment set up to investigate the relationship between distance and willingness to pay for environmental quality changes. The issue is important for the estimation and transfer of benefits. The Choice Modelling experiment allows testing distance effects on parameters of environmental attributes that imply different trade-offs between use and non-use values. The sampling procedure is designed to provide a "geographically balanced" sample. Several specifications of the distance covariate are compared and distance effects are shown to take complex shapes. Welfare analysis shows that disregarding distance produces under-estimation of individual and aggregated benefits and losses, seriously hindering the reliability of cost-benefit analyses.

JEL classification: Q51, H4, D6.

Keyword: Aggregation, Choice Modelling, Distance, Geographical Sampling, Specification Tests.

1. Introduction

There are several reasons to investigate distance effects on environmental preferences. First, distance affects use of environmental goods, information and substitution possibilities that in turns affect preferences (Sutherland and Walsh, 1985). Second, aggregation of individual estimates is generally guided by a political/administrative criterion. Benefits are assumed to differ from zero within given political boundaries and to be nil outside. Identifying distance effects would provide an empirical validation to this criterion (Loomis, 1996). Third, since benefit transfer uses sample (or population) characteristics to transfer estimates from population A to population B, assessing the effect of distance would help in benefit transfer applications (Bateman et al., 1999, Jiang et. al., 2005). Fourth, on a policy level, investigating distance effects can provide useful information regarding the appropriate form of funding for environmental projects (local, state or federal).

To correctly detect distance effects one needs to account for the spatial distributions of the population, and to select the functional form that best represents the distance-value relationship. In Stated Preference (SP) applications, survey response rates tend to decrease as distance from the asset under valuation increases (Bateman and Langford, 1997, Hanley et al., 2003). Random sampling in SP studies is then unlikely to provide a geographically representative sample, and corrective measures are necessary. Given the interplay of use values, non-use values, information and substitution opportunities in shaping environmental benefits, one finds little guidance for choosing among possible functional forms for the distance-values relationship. Tests for different functional forms are required.

Several Contingent Valuation (CV) studies have investigated the relation between values and distance (Sutherland and Walsh, 1985, Loomis, 1996, Pate and Loomis, 1997, Bateman and Langford, 1997, Hanley et al., 2003). Their results are mixed and vary according to the features of the assets under valuation, the sample's geographical distribution, the specified functional form of the distance/WTP relationship and the format of the CV questions.

No attempt has been made so far to estimate a distance-value relationship via the Choice Modelling (CM) technique. Detecting distance effects in CM applications is possibly more important than in CV studies. In open-ended CV, for instance, the population's distribution of WTP is fitted and it doesn't matter what causes its variation as long as the sample is representative of the population. In CM, WTP is predicted from the estimated utility parameters. Omission of distance would produce biased estimates even with a geographically representative sample. Further, distance effects are expected to depend on the use/non-use ratio entailed by each attribute used in CM applications to describe policy options. Hence unbiased distance effects can be estimated only by defining appropriate distance function for each attribute.

This article illustrates how distance effects can be estimated in a CM study of environmental programs. The sampling procedure is designed to provide a geographically balanced sample. Several functional forms are compared via tests for nested and non-nested models. Benefit estimates are presented for two choice models, one that includes and one that omits distance, in order to identify the magnitude and the direction of the bias due to distance omission.

2. The Choice Modelling approach.

The Choice Modelling (CM) approach has been used in a large number of marketing, transportation and health care applications and it is increasingly applied in environmental valuation (Adamowicz, 2004). CM is based on Lancaster's characteristic approach (Lancaster, 1966) and random utility theory. It describes choice behaviour via a function relating the utility U_{ij} of each alternative j for an individual i to the set of the alternative's attributes (Q_j)

and individual characteristics (S_i):

$$U_{ij}=V_{ij}(Q_j, S_i) + \varepsilon_{ij} \tag{1}$$

Utility is partitioned into a systematic component V_{ij} and a random component, ε_{ij}. Because of the random component, the choice problem is inherently stochastic from the point of view of the researcher. Hence, the function linking the probability of an outcome to the utility associated with each alternative can be written as:

$$Pr_{ij}[j \mid Q_j, S_i]=Pr[(U_{ijj})> (U_{ik})] \qquad \forall\, j \neq k \tag{2}$$

or

$$Pr_{ij}[j \mid Q_j, S_i]=Pr[(\varepsilon_{ik}-\varepsilon_{ij})< (V_{ij}-V_{ik})] \qquad \forall\, j \neq k \tag{3}$$

Depending on the distributional properties of the error terms and the design of the experiment, parameters of the deterministic element V_{ij} can be estimated. In the most general form, V_{ij} can be parameterized as follow:

$$V_{ij}=\alpha_j+\Sigma_q\beta_q Q_{jq}+ \Sigma_{qs}\theta_{qs}\, Q_{jq}S_{is} + \Sigma_{js}\varphi_{js}\,\alpha_j\, S_{is} + \Sigma_{js}\psi_{js}\, Q_q Q_p \tag{4}$$

where α_j, β_q, γ_s, θ_{qs}, φ_{js}, ψ_{js} are parameters to be estimated conditional on a vector of intercept terms for J-1 of the J choice options, the matrixes of choice attributes Q, interaction terms of attributes Q_qQ_p, attributes and individual characteristics $Q_{jq}S_{is}$ and intercept terms and individual characteristics. Choice probabilities in equations (2) and (3) depend only on the difference in utilities and only parameters that capture differences across alternatives can be estimated. Hence only J-1 intercept terms are specified and the individual characteristics enter only as interaction terms.

Distance effects can be computed as interactions on the intercept terms or on the attributes. Intercept terms are alternative specific constants (ASC) that capture the average effect on utility of all factors not included in the model. As only differences in utility matter, in CM applications the alternative specific constant for the current policy are usually set to zero. The α's can be easily interpreted as the gains of losses associated with moving away from the status quo. For policy reasons it may be useful to know if individuals living at different distances from the environmental good gain or lose when abandoning the status quo. However, distance is expected to primarily affect the parameter estimates for the attributes. Indeed, attribute variations imply changes in use and non-use benefits, and these benefits are likely to change according to individuals' location. Unbiased parameter estimates require these distance effects to be computed for *each* attribute. The parameter θ_{qs} in (4) measures the change in the attribute parameter β_q caused by distance. Implicit prices I_qs, i.e. the individual WTP for a 1% change of an attribute, can be computed as a function of distance:

$$I_q = (\beta_q + \theta_{qs}\mathrm{DIST}) / \beta_{cost} \tag{5}$$

It is also possible to determine how individual compensating surplus CS_i for a change from policy A to policy B is affected when distance interacts with attributes:

$$\mathrm{CS}_j = -(1/\beta_{cost})*[(\Sigma_q\beta_q\mathrm{Q}_{Aq} + \Sigma_{qs}\theta_{qs}\,\mathrm{Q}_{Aq}\mathrm{DIST}_i) - (\alpha_B + \Sigma_q\beta_q\mathrm{Q}_{Bq} + \Sigma_{qs}\theta_{qs}\,\mathrm{Q}_{Bq}\mathrm{DIST}_i)] \tag{6}$$

where Q_{Aq} and Q_{Bq} are the attribute levels for the two policy options A and B. Since the empirical structure of the utility function - i.e. the model mapping the alternatives' attributes and the individual's characteristics into utility - influences the choice probabilities and hence the predictive capacity of the model, the functional form of the distance variable for each attribute must be selected through a search for the statistically best specification.

3. Survey implementation, sampling and model specification.

The CM survey was designed in consultation with the management authority of Kings Park in Perth (Western Australia). The management authority indicated three major problems in Kings Park's bushland: weeds, trampling, and fires. These problems are common in other protected area in Western Australia. The CM study aimed to help the management authority to prioritise its conservation efforts and investigate the possibility of raising funds to further improve the bushland. This last issue was particularly important, given that state funds for the park are controversial. Three focus groups were organised to identify attributes, levels, the proper format for different management options and test the questionnaire (see Concu, 2005). Table 1 shows the final set of attributes and levels. The *Weed* attribute indicates the percentage of bushland that is free from weed. The *Fire* attribute specifies the average percentage of bushland annually destroyed by fires. The *Accessibility* attribute gives the percentage of the bushland that is accessible to the public. The *Cost* attribute is the contribution via annual income tax required to support the preferred management strategy. A management option illustrates how the park authority can allocate its resource – eradicating weeds, preventing fire or closing the bushland to the public. The systematic variation of the attribute was designed by a Graeco-Latin orthogonal procedure. Respondents were presented with 8 choice sets, each composed by the status quo and two other management options. Socio-economic characteristics were also collected from survey participants (table 2).

The sampling procedure produced a geographically balanced sample by using a stratified random sampling (Ben-Akiva and Lerman, 1985) coupled with the administration of the survey "in waves". The population is stratified according to 11 distance-zones from the park (see Concu, 2005). The 2001 Census (Australian Bureau of Statistics, 2001) gives the proportion of the sample that needs to be drawn from each zone. In the first wave, an equal number of randomly selected West Australian residents was first contacted by phone and received the questionnaire with a reply-paid envelope by mail. Once the questionnaires were returned, response rates and sample shares of each zone were calculated and compared to the population share. Difference between the two suggested the need to adjust the sample and gave the number of contacts in the second wave to be sought in each zone. Following waves further adjusted the sample. Sampling started in June and finished in September 2003. 750 questionnaires were sent, 324 returned and 207 were used for the estimation exercise. The overall response rate is 28%.

The model in (4) is estimated using several different specifications of the distance variable for each attribute. Table 3 lists the different functional forms used in this study. The parameter a_1 and a_2 of the Gamma Transformation are estimated via a grid search. This functional form is chosen because it can represent complex relationships (see, for instance Imber et al., 1991 and Espey and Owusu-Edusei, 2001). The Beckmann's specification is a simplified gravitational model (Beckmann, 1999). In order to choose the best specification, a series of tests is required. Nested models are compared using the likelihood ratio criterion (Louviere *et al*., 2000) that is a test on a particular set of variables. Non-nested models are compared using Clarke's distribution-free test (Clarke and Signorino, 2003).

4. Model results.

Results of the specification tests for nested and non-nested models indicate that for the *Fire* attribute, the preferred specification is the Gamma Transformation; for the *Accessibility* attribute, the best functional form of the distance variable is a Beckmann's specification, while the *Cost* attribute interacts with distance in logarithmic form. No distance effects are recorded for the *Weed* attribute (see Concu, 2005 for more details). The model in (4) is estimated assuming the error terms are i.i.d. extreme value. This hypothesis is at the core of MacFadden's Conditional Logit (Greene, 2003). Results are reported in table 4 for a model that omits distance interactions and a model in which distance interacts with the attributes according to the preferred specifications. For both models, likelihood Ratio tests suggest the set of independent variables to be included in the estimation model.

In both models, the significant negative sign of the ASC indicates that the utility associated with moving away from the status quo is negative. For the *Weed* attribute, income and environmental attitude (*EnvAtt=1*) have both significant and positive parameters. No distance effects are recorded. Income and environmental attitude are significant, but negative, also for the *Fire* attribute. Higher levels of the *Fire* attribute represent increased fire damages in the park. Hence, the negative coefficients indicate a willingness to pay to prevent these damages. Distance effects on the *Fire* attribute are captured by a Gamma Transformation with parameters $a_1=-3$ and $a_2=6$ obtained by a grid search procedure. Figure 1 depicts the complex behaviour in space of the implicit price of *Fire* attribute, calculated using equation (5). WTP for fire prevention in Kings Park decreases with distance and then increases again. It appear that country people are more concerned about fires, maybe because more familiar with fire events. Effects of distance on the third attribute are decreasing (figure 1). Reducing accessibility to Kings Park bushland concerns less residents living far away from the park. Other variables affect the magnitude of the values for the *Accessibility* attribute. More educated, more informed and respondents with more children prefer more bushland is accessible. The *Cost* attribute has a negative and significant parameter, as expected. Income and distance effects are also negative.

Implicit prices as functions of distance (figure 1) tend to asymptotes and the gains or losses associated with each attribute change become distance-independent. In the light of these distance effects, it can be stated that state funds for Kings Park are justified. The market area for Kings Park is at least as large as Western Australia. It is not possible to say, however, if federal resources are appropriated. The sampling frame is indeed constrained to the Western Australian residents. Crossing a state border is expected to cause spatial discontinuity, preventing extrapolating these results to the population of another state.

The consequences of omitting distance on individual parameters can be assessed comparing the models in table 4. *t*-tests on the hypothesis that the parameters of the models with and without distance are equal is strongly rejected for all parameters except the ASC, the base coefficient for *Weed* and the interaction between environmental attitude and the *Weed* attribute. For most of the 22 significant coefficients, the omission of distance determines underestimation of the parameter and larger standard errors.

Aggregated welfare measures for Kings Park's bushland management strategies are computed using equation (6) and information on the spatial distribution of West Australians (Australian Bureau of Statistics, 2001). The benefits from the status quo (V_0) are compared with the benefits from five other management scenarios (V_1). The consequences of ignoring distance and assuming a uniformly distributed population are illustrated in table 5. Gains from implementing a scenario are indicated by negative figures. Distance omission determines gross underestimation of benefits (scenario 5) and losses (scenario 4). More important, for scenarios 1 to 3, the consequences of omitting distance are so severe that it turns benefits into losses and vice versa. Such an outcome can easily lead to an inefficient allocation of resources. Table 6 tells also that the value the public assigns to the actual services of the bushland equal around Au$10.2 million (scenario 4). Contrasting this figure with the amount of money the park authority actually spends on the bushland (Au$330.000), shows that there is huge scope for increasing public funding of the park.

5. Conclusion.

This article investigates how distance effects can be accounted for in a Choice Modelling application. The issue is relevant when using such an approach because of its multi-attribute nature. It is necessary not only a sample that represents the geographical distribution of the population, but also accurate specification tests for the distance variable. The study illustrates the gross underestimation of benefits and losses determined by distance omission. It also shows that it is possible to determine how large the smallest area for aggregation purposes is. For fiscal policy, including distance in benefit estimation can provides rationale for a local, state or federal taxation. This article demonstrates that for the park under valuation, state funding is appropriate. The study also shows that while is possible to identify the smallest area for aggregation, the sampling frame limits the possibility to make out-of-sample predictions, especially when there are factors, such as the crossing of administrative boundaries, which may induce spatial discontinuity of benefits.

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Table 1. Attributes and levels.

Attributes	Levels	Variable in Model
Weed-free Bushland (in %)	30, 40 (sq)*, 50, 60	**Weed**
Bushland annually destroyed by Fire (in %)	1, 3, 6 (sq)*, 9	**Fire**
Bushland accessible to the Public (in %)	25, 50, 75, 100 (sq)*	**Acc**
Cost (in $)	0.30 (sq)*, 1, 3, 6	**Cost**

*(sq) = status quo levels

Table 2. Socio-economic characteristics of respondents.

Variable	Type	Meaning
EnvAtt	Categorical	Environmental attitude
Rank	Categorical	Ranking of environmental issues
Info	Continuous	Respondents' knowledge of KP
Subst	Categorical	# of substitutes for Kings Park
Distance	Continuous	Geographical distance from Kings Park
Gender	Categorical	
Age	Continuous	Age of the respondent
Child	Continuous	Number of children in the household
Country	Categorical	Country of origin:
Educ	Categorical	Attained level of education:
Empl	Categorical	Employment status
Income	Continuous	Weekly individual income
Org	Categorical	Membership in environmental organizations

Table 3. Functional forms of the distance variable.

Function	Formula
Linear	$DIST2=a_0 DIST1$
Logarithmic	$DIST2=a_0 \ln(DIST1)$
2nd Polynomial	$DIST2=a_0 DIST1+a_1 DIST1^2$
3rd Polynomial	$DIST2 = a_0 DIST1 + a_1 DIST1^2 + a_2 DIST1^3$
Gamma	$DIST2 = a_0 (DIST1)^{a_1} e^{(a_2 DIST1)}$
Exponential Law	$DIST2 = a_0 \exp(-DIST1)$
Beckmann Law	$DIST2 = \dfrac{a_0}{1 + DIST1^2}$

Table 4. Results of the Conditional Logit Models.

	Distance included			Distance omitted		
Observations	4968			4968		
Log Likelihood	-1556.330			-1569.118		
Pseudo R2	0.1445			0.1375		
Variable	Coef.	St.Err.	P>|z|	Coef.	St.Err.	P>|z|
ASC	-0.218*	0.091	0.016	-0.217*	0.091	0.017
Weed	-0.082**	0.041	0.043	-0.081**	0.041	0.045
weed*ln(income)	0.013**	0.006	0.030	0.012**	0.006	0.033
weed*att(=1)	0.035***	0.009	0.000	0.035***	0.009	0.000
weed*subst(=1)	-0.017	0.013	0.197	-0.016	0.013	0.212
weed*subst(=2)	0.011	0.012	0.357	0.012	0.012	0.326
weed*subst(=3 or more)	0.013	0.012	0.279	0.014	0.012	0.220
weed*subst(na)	-0.009	0.017	0.592	-0.010	0.017	0.542
Fire	0.152	0.142	0.285	0.185	0.141	0.191
fire*ln(income)	-0.034*	0.020	0.096	-0.032	0.020	0.111
fire*distance(GAMMA)	32.097***	8.597	0.000	-	-	-
fire*att(=1)	-0.072**	0.032	0.025	-0.022***	0.032	0.024
fire*subst(=1)	0.005	0.047	0.916	-0.090	0.046	0.632
fire*subst(=2)	-0.074	0.045	0.100	0.018**	0.044	0.042
fire*subst(=3 or more)	0.055	0.044	0.209	0.030	0.042	0.667
fire*subst(na)	-0.007	0.062	0.907	-0.004	0.060	0.618
Accessibility	-0.038*	0.019	0.052	-0.002	0.015	0.782
acc*ln(income)	-0.001	0.002	0.431	-0.003	0.002	0.276
acc*distance(beckmanns')	0.031***	0.012	0.007	-	-	-
acc*att(=1)	-0.004	0.003	0.196	0.022	0.003	0.227
acc*rank(=4)	0.023***	0.007	0.001	0.013***	0.007	0.002
acc*rank(=3)	0.014**	0.007	0.033	0.008**	0.007	0.047
acc*rank(=2)	0.008	0.007	0.244	0.013	0.007	0.261
acc*rank(=1: less important)	0.014*	0.007	0.067	-0.009*	0.007	0.082
acc*subst(=1)	-0.010**	0.004	0.014	-0.010**	0.004	0.029
acc*subst(=2)	-0.011***	0.004	0.004	-0.008**	0.004	0.012
acc*subst(=3 or more)	-0.010***	0.004	0.008	-0.002**	0.004	0.023
acc*subst(not applicable)	-0.003	0.005	0.619	-0.012	0.005	0.772
acc*country(overseas)	-0.012***	0.002	0.000	0.008***	0.002	0.000
acc*educ(=Y12)	0.006**	0.003	0.050	0.008**	0.003	0.024
acc*educ(=cert)	0.009**	0.003	0.012	0.006***	0.003	0.007
acc*educ(uni)	0.008***	0.003	0.004	-0.006*	0.003	0.059
acc*org(=1)	-0.006**	0.003	0.048	0.000**	0.003	0.041
acc*# of children	0.002**	0.001	0.047	0.002**	0.000	0.011
acc*Information Index	0.000**	0.000	0.012	-0.089**	0.001	0.046
Cost	-0.216***	0.065	0.001	-0.089**	0.042	0.033
cost*income	0.000***	0.000	0.000	0.000***	0.000	0.000
cost*ln(distance)	-0.038***	0.014	0.009	-	-	-

*** significant at 1%
** significant at 5%
* significant at 10%
(a) **Subst(na)**= groups non-users and respondents that did not provide answer to the number of substitutes.

Table 5. Aggregate benefits for alternative management strategies (in Aus $).

Management Alternative			Models: Distance included	Models: Distance omitted
Status Quo				
Fire	Weed	Acc		
6	40	100		
Scenario 1				
Fire	Weed	Acc	-3,668,910	2,291,707
6	60	100		
Scenario 2				
Fire	Weed	Acc	-8,343,830	1,033,502
1	40	100		
Scenario 3				
Fire	Weed	Acc	82,617	-1,607,847
6	40	75		
Scenario 4				
Fire	Weed	Acc	10,225,618	2,019,388
9	30	100		
Scenario 5				
Fire	Weed	Acc	-11,171,536	-1,580,110
3	60	75		

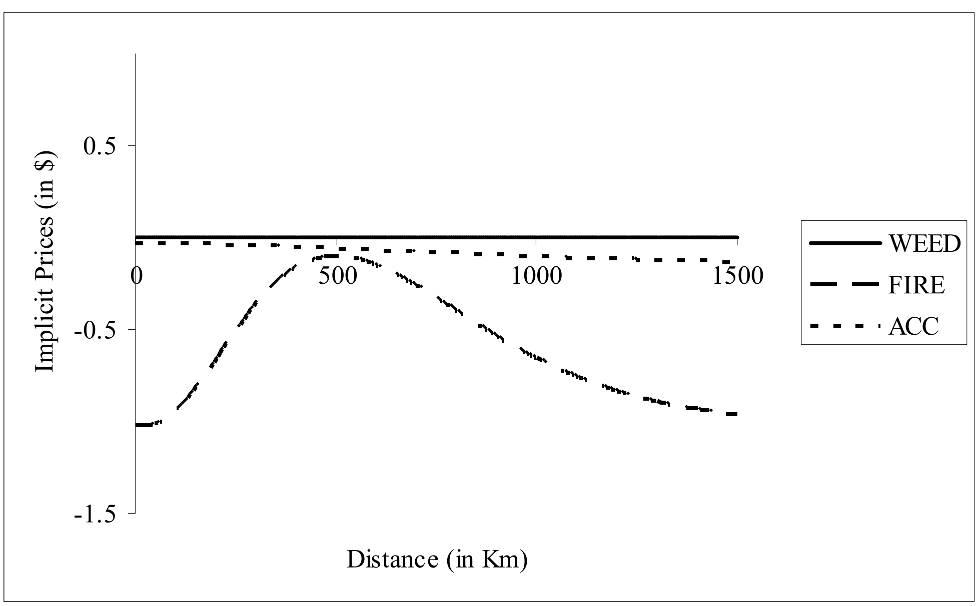

Figure 1. Effects of distance on implicit prices.