WESTERN REGIONAL RESEARCH PUBLICATION

W-133
BENEFITS AND COSTS OF RESOURCES POLICIES AFFECTING PUBLIC AND PRIVATE LAND

12TH INTERIM REPORT
JUNE 1999

Compiled by
W. Douglass Shaw

Department of Applied Economics and Statistics
Mail Stop 204
University of Nevada
Reno, Nevada 89557-0105

INTRODUCTION

This volume contains the proceedings of the 1999 W-133 Western Regional Project Technical Meeting on "Benefits and Costs of Resource Policies Affecting Public and Private Land." Some papers from W-133 members and friends who could not attend the meeting are also included. The meeting took place February 24th - 26th at the Starr Pass Lodge in Tucson, Arizona. Approximately 50 participants attended the 1999 meeting, are listed on the following page, and came from as far away as Oslo, Norway.

The W-133 regional research project was rechartered in October, 1997. The current project objectives encourage members to address problems associated with: 1.) Benefits and Costs of Agro-environmental Policies; 2.) Benefits Transfer for Groundwater Quality Programs; 3.) Valuing Ecosystem Managment of Forests and Watersheds; and 4.) Valuing Changes in Recreational Access.

Experiment station members at most national land-grant academic institutions constitute the official W-133 project participants. North Dakota State, North Carolina State, and the University of Kentucky proposed joining the group at this year's meeting. W-133's list of academic and other "Friends" has grown, and the Universities of New Mexico and Colorado were particularly well represented at the 1999 W-133 Technical Meeting. The meeting also benefitted from the expertise and participation of scientists from many state and federal agencies including California Fish and Game, the U.S. Department of Agriculture's Economic Research and Forest Services, the U.S. Department of Interior's Fish and Wildlife Service, and the Bureau of Reclamation. In addition, a number of representatives from the nation's top environmental and resource consulting firms attended, some presenting papers at this year's meeting.

This volume is organized around the goals and objectives of the project, but organizing the papers is difficult because of overlapping themes. The last section includes papers that are very important to the methodological work done by W-133 participants, but do not exactly fit one of the objectives. -- I apologize for the lack of consistent pagination in this volume.

On A Personal Note... Any meeting or conference is successful (and fun!) only because of its participants, so I would first like to thank all the people who came and participated in 1999 - listed below. I also want to thank Jerry Fletcher for all his help at this meeting and prior to it, and John Loomis who passed on his knowledge of how to get a meeting like this to work, and who continues to have the funniest little comments to lighten the meetings up. I especially thank Paul Jakus, who helped me to organize this conference and have a lot of fun during it and afterward. Finally, I want to thank Nicki Wieseke for all her help in preparing this volume, and Billye French for administrative support on conference matters.

W. Douglass Shaw, Dept. of Applied Economics & Statistics, University of Nevada, Reno.
June, 1999

P.S. P.F. and J.C. - As far as I can tell, that darn scorpion is still dead!

ESTIMATING MULTIPLE-NESTING-STRUCTURES IN A SINGLE RANDOM UTILITY MODEL: AN APPLICATION TO FRESHWATER FISHING

Doug MacNair
Catherine Taylor

Triangle Economic Research
1000 Park Forty Plaza
Suite 200
Durham, NC 27713

Phone: 919-544-2244

April 30, 1999

INTRODUCTION

Nesting is the most frequently employed method for overcoming the restrictive properties of the random utility model (RUM). Models without nests assume the errors across all alternatives within the choice set are independently and identically distributed (i.i.d.), which is often an unrealistic assumption. Nested models are less restrictive because they construct groups of alternatives which share similar, but unobserved characteristics. Nested models impose the i.i.d. assumption on alternatives within the same group, but across groups the error distribution can vary.

In order to utilize the advantageous statistical properties of the nests, the researcher usually chooses a single behavioral model that describes the anglers decision process. Within these single-nesting-structure models, the behavioral model is often viewed as the process that generates the similar, but unobserved characteristics shared by alternatives within a nest. However, the nesting structure can also be a purely statistical artifact of the data and not necessarily behavioral. For example, fishing sites may be grouped into rivers and lakes. Anglers might be described as first choosing whether to fish at a lake or a river based on personal characteristics. Once that decision has been made, the angler then chooses among the sites within that nest. An alternative view of the nests might be that the quality of the data for the site characteristics varies significantly between rivers and lakes, which induces different degrees of correlation among the errors for each type of site.

Alternative single-structure nested models are often viewed as mutually exclusive; the researcher must choose one nesting structure. However, Kling and Thomson (1996) have shown that the choice of nesting structure can have a significant impact on the welfare calculations. Therefore, the choice of nesting structure needs to be made carefully. The Kling and Thomson results show that the most "natural" structure, based on type of fishing trip, does not perform as well as other, more counter-intuitive models. This lends support to the view that the appropriate nests are statistical and not behavioral. It also complicates the researcher's job because it may not be possible to find the most appropriate nesting structure by relying on economic intuition.

Our paper develops a flexible method for determining the appropriate nesting structure that overcomes some of the limitations of single-nesting-structure models. It also suggests there may be a behavioral basis for designing nesting structure. Alternative nesting structures need not be mutually exclusive; different structures may apply to different groups within the sample. Rather than impose one decision process and nesting structure, we estimate a multiple-nesting-structure RUM based on a finite mixture approach (Shonkwiler and Shaw, 1997, Titterington, Smith and Makov 1985). Section 1 compares the single and multiple-nesting-structures and shows how the later significantly reduces the i.i.d. assumption. Section 2 describes the data. Section 3 describes the model results. Section 4 describes the welfare calculations. Section 5 describes future research.

1. NESTING STRUCTURES

One consequence of assuming that errors are independently and identically distributed in a conditional logit model is the independence from irrelevant alternatives (IIA) property. That is, the model prescribes the ratio of choice probabilities between two alternatives to be solely a function of the characteristics of the two alternatives. Whether or not the assumption is justified is an empirical question. In general, it is better not to impose this assumption a priori.

Single-structure nested models reduce, but do not eliminate this restriction. For example, suppose we nest fishing trips based on whether they occur at rivers or lakes and assume that there are only two sites of each type. Using Morey's (1997) basic notation for a repeated nested model[1], the choice probability ratio for the first lake site (Lake_1) vs. the first river site (River_1) is:

$$\frac{P(\text{Lake}_1) = \dfrac{L_1(L_1^{SL} + L_2^{SL})^{(1/SL)-1}}{(L_1^{SL} + L_2^{SL})^{1/SL} + (R_1^{SR} + R_2^{SR})^{(1/SR)-1}}}{P(\text{River}_1) = \dfrac{R_1(R_1^{SR} + R_2^{SR})^{(1/SR)-1}}{(L_1^{SL} + L_2^{SL})^{1/SL} + (R_1^{SR} + R_2^{SR})^{(1/SR)-1}}}$$

---

[1] We use Morey's notation for the similarity coefficient. Morey's SR is equivalent to McFadden's $1/(1-\sigma_R)$

where $L_i = \exp(X_i\beta)$, the exponentiated utility index for lake site i=1,2 , and $R_i = \exp(X_i\beta)$ for river sites i=1,2. and SR and SL are the similarity coefficients for alternatives within the nest. For choices across nests, this expression simplifies to:

$$\frac{P(\text{Lake}_1)}{P(\text{River}_1)} = \frac{L_1(L_1^{SL} + L_2^{SL})^{(1/SL)-1}}{R_1(R_1^{SR} + R_2^{SR})^{(1/SR)-1}}$$

Therefore, this probability ratio allows for dependence on alternatives other than Lake_1 and River_1 and the IIA assumption is not imposed. However, the probability ratio between the two lake sites is simply L_1 / L_2 and therefore imposes the IIA assumption.

A multiple-nesting-structure model further reduces reliance on the IIA assumption. The multiple-nesting-structure model employs a finite-mixture approach to estimate which nesting structure is most appropriate for each trip in the sample. This approach adds another layer to the nesting structure to estimate the probability a trip belongs within a particular nest. Figure 1 provides an overview of the approach. Suppose we have two alternative nesting structures—A, which is river vs. lake, and B, which is major vs. non-major fishing site, as defined by a popular angler resource book. Instead of forcing the researcher to choose between the two nesting structures, the multiple-nesting-structure model uses the characteristics of the individual or the trip to determine which nesting structure is best suited for that trip. The probability of choosing site j on trip i (Pij) is:

$$P_{ij} = (P_i(NSA)P_{ij}^A + (1 - P_i(NSA))P_{ij}^B$$

where,

$$P_i(NSA) = \frac{1}{1 + \exp(\lambda Z_i)}$$

$P_i(NSA)$ is the probability that a trip is best described by nesting structure A and is a function of the characteristics of the trip Z_I. Only if $P_i(NSA)$ = 1 or 0 for all cases would either of the single-structure nested models be preferred to the multiple-nesting-structure model.

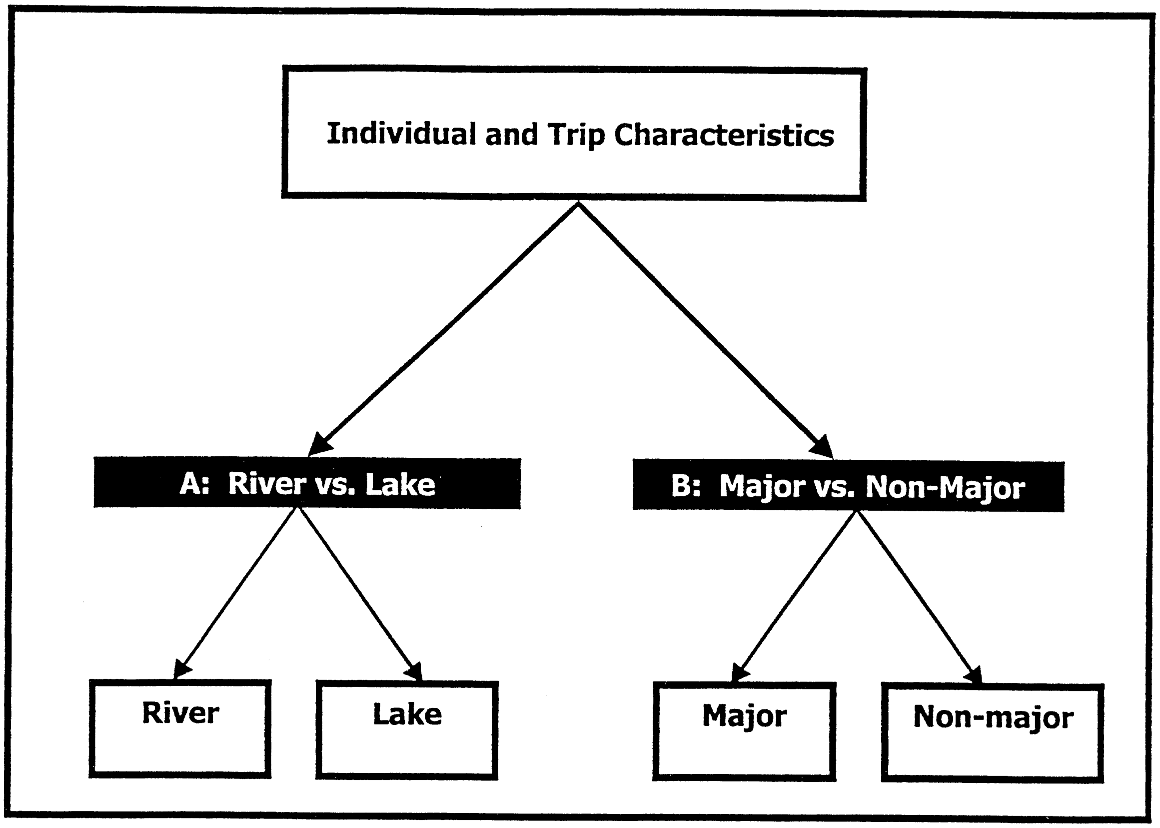

Figure 1.
Multiple-Nesting-Structure Model

The reduction in the need for the IIA assumption using this model can be seen by looking at the probability ratios. Using our original example, nesting structure A is still rivers vs. lakes, but in nesting structure B (major vs. non-major fishing water body), the nests are Lake$_1$, River$_1$ and Lake$_2$, River$_2$. The probability ratio for Lake$_1$ and Lake$_2$ no longer depends on only those two alternatives:

$$\frac{\mathrm{P(Lake_1)}}{\mathrm{P(Lake_2)}} = \frac{\mathrm{L_1[P_i(NSA)(L_1^{SL} + L_2^{SL})^{(1/SL)-1} + (1 - P_i(NSA))(L \quad + R_1)^{(1/SM)-1}]}}{\mathrm{L_2[P_i(NSA)(L_1^{SL} + L_2^{SL})^{(1/SL)-1} + (1 - P_i(NSA))(L_2 + R_2)^{(1/SNM)-1}]}}$$

In general, the IIA assumption is only necessary between alternatives that are in the same nests in both nesting structure A and B for trips that have identical P_i(NSA). Overall, the multiple-nesting-model will significantly reduce the instances where IIA is assumed to be valid.[2]

The potential improvement from a multiple-nesting-structure model can also be seen when comparing hypothesis testing of multiple vs. single structure models.[3] Of course, there are many ways in which the data can be nested in a single-structure model. Typically, one would estimate several models then choose a single structure based on whether or not the similarity coefficients are correct (>1) or based on a model selection criteria such as the Pollack and Wales (1991) likelihood dominance criteria (LDC).

The LDC is used for comparing "non-nested" models. Here the term "non-nested" is unrelated to the nesting as described above. "Non-nested" models are situations in which we want to compare two competing models and one model cannot be stated as a restricted version of the other model. Also, LDC can be used when a composite model that incorporates both models cannot be designed and when the hypothesis that one of the two models performs better cannot be tested.

For example, a model with no nesting structure can be directly compared to a nested (e.g., river vs. lake) model because the no-nest model is a restricted version of the river/lake nested model. A no-nest model imposes the restriction that SL and SR are both equal to one. Therefore, it is a restricted version of the nested model, and standard hypothesis tests can be employed.

---

[2] A single-structure model could also be based on four nests: major lakes, non-major lakes, major rivers, and non-major rivers. We are currently exploring the relationship between this model and the multiple-nesting-structure approach.

[3] We are grateful to Kerry Smith for pointing this out.

However, when comparing two nested models, neither nesting structure is a restricted version of the other, and the standard hypothesis tests do not apply. An alternative approach would be to construct a single composite model (Davidson and McKinnon, 1993):

$$P_{ij} = (\alpha)P_{ij}^{A} + (1-\alpha)P_{ij}^{B}$$

where the two superscripts refer to the probabilities estimated under alternative nesting structures A, B. Therefore, we've created a composite model that incorporates the two alternative models. If the composite model could be estimated, the result α=1 would support accepting nesting structure A while the result α=0 would support acceptance of nesting structure B.

The LDC recognizes that it is often impossible to parameterize and estimate a composite model. Pollack and Wales describe the conditions under which the differences in the log-likelihood between two competing non-nested models are large enough to assume that one model dominates the other with adjustment for the difference in the number of parameters in the two models. Therefore, the composite model need not be estimated, but the models can be compared. This is the approach used by Kling and Thompson.

A multiple-nesting-structure model can be viewed as a composite model that obviates the need to choose among competing nested models. P_i(NSA) = α and only if α=1 or 0 for all cases would either of the nested models be preferred to the composite model. In other words, the two alternative single-structure nested models are restricted versions of the multiple-nesting-structure model. This additional flexibility should improve the performance of the RUM models.

2. DATA

This study uses data from a 14 month panel survey of Montana anglers from July 1992-August 1993. The respondents were recruited using random-digit dialing and 75% of anglers agreed to participate. Once recruited, the respondents were sent a trip diary every two months in which to record details of their fishing trips. The respondents then were called and asked to read back the information from their trip summaries to the interviewer. The response rates for each of the seven panels range from 61 to 78 percent. In total, 2,919 trips were reported. After removing trips that lack key information and trips lasting for more than one day, 1,473 trips remain for use in this analysis. Table 1 provides demographic information of survey respondents, and Table 2 provides key information on the trips used in this analysis.

Table 1.
Demographic Information on Survey Respondents

VARIABLE	MEAN	STANDARD DEVIATION
AGE	41	15.19
INCOME ($1992)	26,011	17,995
OWNBOAT	0.43	0.50
FEMALE	0.37	0.48

Table 2.
Trip Characteristics

VARIABLE	MEAN	STANDARD DEVIATION
TARGET TROUT	0.65	0.48
MAJOR SITE	0.63	0.48
RIVER SITE	0.51	0.50

The choice set for this model is comprised of 182 river sites and 71 lake sites. In most cases, the lake sites are defined around a single lake. River site definitions are based on Montana River Information System river reaches, the smallest segments of each river. The fishing sites are characterized using the variables listed in Table 3.

Table 3.
Description of Site Variables

VARIABLE	DESCRIPTION	MEAN	STANDARD DEVIATION
Specific to Lake Sites			
BIODUM	Dummy variable for lakes with "abundant" fish.	0.54	0.50
CGCIRC	Number of campgrounds relative to circumference of lake.	0.14	0.24
LOGAREA	Log of the surface area of the lake.	5.59	2.11
Specific to River sites			
BIOMASM	Biomass rating measure of pounds per 1,000 feet of river.	82.94	154.85
SRAMILE	Number of State Recreation Areas per mile of river reach.	0.03	0.07
LCTYMILE	Number of large cities (pop. > 10,000) within 30 miles of river reach, divided by reach length.	0.06	0.09
LOGLNGTH	Log the length of reach in miles.	2.59	0.71
AESMDUM1	Aesthetics rating for rivers.	0.20	0.40
Specific to both Lake and River sites			
MAJOR	Dummy variable for site defines as major fishing sites.	0.35	0.48
RIVER	Dummy variable for river sites	0.72	0.45
TRIPCOST	Costs of trip calculated as trips costs plus maintenance costs plus oil costs.	19.83	17.14

3. RESULTS

For this analysis, we first nest the data using two different schemes: river vs. lake and major vs. non-major.[4] The model results are reported in Tables 4 and 5. In both models, all the variables have the expected sign and are significant at the 90-percent confidence level with the exception of BIODUM in the lake nest of the river vs. lake nesting structure. The Pollack and Wales LDC (1991) points to the river vs. lake nesting structure as the better model as its log-likelihood is -4698 while the major vs. non-major nesting structure yields a log-likelihood of –4851. The river vs. lake model has just one more parameter and the improvement in the log-likelihood passes the χ^2 test at all normal levels of significance. In addition, the similarity parameters (SR and

SL) are both greater than one in the river vs. lake model, which is consistent with utility-maximization theory. For the major vs. non-major nesting structure, SNM is less than one. This condition supplies further evidence that the river vs. lake nesting structure is the more appropriate of the two.

Table 4.
Results from River vs. Lake Nesting Structure

NEST	VARIABLE	PARAMETER
R	AESMDUM	0.54**
R	LOGLNGTH	0.06**
R	SRAMILE	0.96**
R	MAJOR	0.34**
L	LOGAREA	0.16**
L	BIODUM	0.28
L	MAJOR	0.22**
Both	TRAVCOST	-0.05**
	SR	1.84**
	SL	2.06**

Mean LL = -3.189 McFadden's R^2 = 0.42

Table 5.
Results from Major vs. Non-Major Nesting Structure

NEST	VARIABLE	PARAMETER
M	BIODUM	1.12**
M	LOGAREA	0.30**
M	LAKE	-1.31**
NM	BIODUM	0.50**
NM	LOGAREA	0.28**
NM	LAKE	-0.69**
Both	TRAVCOST	-0.10**
	SM	0.81**
	SNM	1.06**

Mean LL = -3.293 McFadden's R^2 = 0.40

The results for the model utilizing the multiple-nesting-structure model are presented in Table 6. This model uses the same specification as the two separate

---

[4] The designation of a site being a major site comes from "The Angler's Guide to Montana" by Michael S. Sample (1984).

nested models. The similarity coefficients for all four nests are now all greater than 1 and consistent with utility maximization. The log-likelihood for the multiple-nesting-structure model is significantly higher than log-likelihoods for the two single-structure models. This suggests that it would be inappropriate to impose either structure individually on the entire data set.

The results clearly show that different nesting structures apply to different trips. The positive and significant coefficient on OWNBOAT implies that trips by people owning boats are more likely to be best modeled using the major vs. nonmajor nesting structure. The negative and significant coefficient on TARGET TROUT shows that trips taken to target trout are best modeled using the lake vs. river nesting structure. Boat owners who target trout are slightly more likely to fall into nesting structure B. Across the entire sample the average P_i(NSA) is .601, which means that more trips fall into the river vs. lake nesting structure. This is consistent with the result that the single-structure river vs. lake nest works better than the major vs. non-major. Other variables such as age, income and gender were not significant in the model.

As stated previously, nests are generated to group sites believed to have similar but unobserved characteristics. The multiple-nesting-structure model allows the similarities to be in the eye of the beholder, i.e. the trip-taker. Additionally, the discovery of behavioral indicators of appropriate nesting structure provides evidence that nesting structure has an important behavioral component.

Table 6.
Results from Multiple-Nesting Structure Model

STRUCTURE	NEST	PARAMETER	ESTIMATE
		CONSTANT	-0.30
		OWNBOAT	1.71**
		TARGET TROUT	-1.61**
River vs. Lake	R	SR	1.25**
	L	SL	1.58**
Major vs. Non-Major	M	SM	1.28**
	NM	SNM	1.56**
Both	Both	TRIPCOST	-0.07**
River vs. Lake	R	AESMDUM	0.85**
	R	LOGLNGTH	0.13**
	R	SRAMILE	1.48**
	R	MAJOR	0.45**
	L	LOGAREA	0.02
	L	BIODUM	1.09**
	L	MAJOR	0.36*
Major vs. Non-Major	M	BIODUM	0.15
	M	LOGAREA	0.32**
	M	LAKE	0.94**
	NM	BIODUM	0.05
	NM	LOGAREA	0.39**
	NM	LAKE	-0.03

Mean LL = -3.122 McFadden's $R^2 = 0.44$

4. WELFARE CALCULATIONS

Competing models often are compared based on welfare measures. The compensating variation is computed using a simulated change in a policy-related variable such as catch rate or a particular site closure. The potential problem with this approach is that the results may be sensitive to the policy variable or the site chosen for the simulation. To provide a more comprehensive comparison of the models, we simulate the closure of each of the 253 sites and calculate change in compensating variation.

For the multiple-nesting-structure model, we simply multiply the CV from each nesting structure by the probability that the trip is in that nesting structure:

$$CV_{ij} = P_i(NSA_i)CV_{ij}^{A} + (1 - P_i(NSA))CV_{ij}^{B}$$

Table 7 summarizes the results for the three estimated models. For this set of models, there are no discernable differences between the average site values from the models. However, the range of estimates from the multiple-nesting-structure model has a larger standard deviation than the other models. This may indicate that this model provides more sensitive estimates by allowing CV estimates to differ by angler and type of trip.

Table 7.
Consumer Surplus Estimates from Site Closures

NESTING STRUCTURE	MIN	MEAN	MAX	STANDARD DEVIATION
River vs. Lake	\$0.001	\$0.046	\$0.908	0.0804
Major vs. Non-Major	0.001	0.048	0.436	0.0604
Multiple	0.001	0.047	0.983	0.0954

5. CONCLUSION

Multiple-nesting-structure models provide a flexible method for further relaxing the restrictive assumptions of a conditional logit model. Rather than imposing a single nesting structure on data, the approach developed here allows the data to determine which structure best applies to each trip. The results suggest that multiple-nesting-structure models may outperform single-nested models, although for this application there is not a significant impact on the welfare calculations.

This analysis also suggests that there may be a behavioral basis for determining nesting structure. Montana anglers who own boats appear to group sites according to waterbody type, i.e. river or lake. In contrast, anglers who target trout are more likely to group sites according the quality of the site. The extent to which sites share similar, but unobserved, characteristics appears to be a function of the characteristics of the potential users of the site.

To further refine multiple-nesting-structure approach, our future research will focus on identification conditions. Testing this approach with other datasets will provide additional insights into this issue. Identification can be a problem with any probabilistic allocation of the sample among alternative model structures. Therefore, we also intend to compare this probabilistic approach with a deterministic approach, whereby trips are assigned to nesting structure based on responses to survey questions about their decision process. This should provide a better understanding of the behavioral basis for nesting structures.

REFERENCES

Davidson, R. and James G. MacKinnon. “Estimation and Inference in Econometrics.” Oxford University Press. 1993. p 381-389.

Kling, Catherine L., and Cynthia J. Thomson. “The Implications of Model Specification for Welfare Estimation in Nested Logit Models.” *Amer. J. Agr. Econ.* 78 (February 1996): 103-114.

Morey, Edward. “Two RUMs unCloaked: Nested-Logit Models of Site Choice and Nested-Logit Models of Participation and Site Choice”. Forthcoming as Chapter 4 in “Valuing the Environment Using Recreation Demand Models,” (C.L. Kling and J.A. Herriges, Eds.) Edward Elgar Publishing Ltd.

Pollak, R., and T. Wales. “The Likelihood Dominance Criterion.” *J. Econometrics* 47(1991):227-42.

Shonkwiler, J. Scott, and W. Douglass Shaw. “Shaken, Not Stirred: A Finite Mixture Approach To Analyzing Income Effects In Random Utility Models.” Selected paper for AAEA Annual Meetings. Toronto. August 1997.