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Rationed Access and Welfare: Case of Public Resource Lotteries

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Abstract

Pressures on public lands and waterways are resulting increasingly in the rationing of public access by lottery. Upon accounting for the uncertainties of random rationing, discrete choice models lend themselves to analyzing participation in public resource lotteries and estimating welfare changes. Key to valuing lottery-rationed rights is accounting for changes in access probabilities that result from policy changes. The empirical application models the discrete choices of more than 18,000 participants in a New Mexico lottery system for elk harvest rights. Welfare estimates are obtained from simulated policy changes that affect, individually and jointly, the access probability and indirect utility.

I. INTRODUCTION

Pressures on natural resource stocks and habitats on public lands and waterways are resulting increasingly in the rationing of public resources and access opportunities by lottery. The merits of lotteries as rationing mechanisms can be debated (e.g., relative to auctions or queues), just as the merits of public lands management can be debated relative to alternative institutional arrangements (e.g., privatization). What cannot be debated is the prevalent use of lotteries in the United States and elsewhere. Since lotteries ration independently of income, they are commonly favored by the public due to equity concerns.

Regardless of the particular good being rationed, a common characteristic of lottery participation is that it involves discrete choice. If the lottery rations a fixed quantity of a stock or access opportunities, the choice occasion involves a participation decision; if multiple lotteries are used to ration quantities of heterogenous goods, the occasion additionally involves a selection from a set of alternatives. Thus, lottery demand and welfare analyses appear amenable to discrete choice methods, such as random utility models (RUMs). While many aggregate lottery demand models have been explored (e.g., Loomis, 1982; Nickerson, 1990; Scrogin, Berrens and Bohara, 2000), the unit of analysis will ideally be the individual. Yet individual-level approaches for modeling lottery participation remain relatively under-investigated (Boxall, 1995; Akabua, Adamowicz and Phillips, 1999).

What makes lottery systems particularly interesting for demand and welfare analysis is that unlike auctions, queues and merit systems, lotteries randomly allocate resources. As such, participants choose alternatives under uncertainty. Further, changes in access probabilities are a likely result of altered policy. Thus, when access opportunities are rationed, discrete choice analyses and benefits estimation must be amended appropriately. Building upon the sparse, existing literature, this paper develops a two stage, random expected utility model (REUM) for lottery demand and welfare analysis. Particular attention is given to benefits estimation.

Key to analyses of gambling-related activities (with individual or aggregate data), such as lottery choice, is the construction of an ex ante, subjective probability of winning. We estimate expected access probabilities by modeling the observed outcomes (i.e., being drawn or not) of more than 29,000 participants in 215 lotteries for big-game harvest rights in the western United States. The choice of lottery made by a large subset of these participants (approximately 19,000) is then modeled. Our approach is similar to recently proposed models of recreational angler expected catch and site choice, where the former are used to generate an expectation of catch at each site, and allows predicted changes in access probabilities to be readily obtained.

The paper is structured as follows. Section II provides background information on lotteries for rationing public resources. In section III an expected utility model is developed from which associated welfare measures follow. The econometric models, data and estimation results are presented in section IV, and section V explores the welfare implications of amendments to lottery systems. Compensating surplus is estimated for simulated policy changes that affect, individually and jointly, the access probability and utility function. For comparison, traditional RUMs (which ignore access probabilities) are also examined. Section VI concludes.

II. BACKGROUND: LOTTERIES FOR RATIONING SCARCE PUBLIC RESOURCES

A primary concern for resource managers is to allocate stocks and access rights in an equitable fashion, while maintaining quality or protecting the recreational experience (e.g., managing herd size or restricting congestion). When quantities are fixed and prices set below those that would prevail in a market setting, shortages are an expected result. Because lotteries ration without regard to income, they have become a common means for allocating stocks and recreational access rights.[1] While lotteries are used in a variety of public resource settings, our focus is their common use for allocating access rights.[2] Lottery-rationed recreation is widespread across the U.S. and Canada, and this section gives a flavor for the wide-ranging applications.

Prominent lotteries for river rafting include: The Bureau of Land Management's Westwater Canyon lottery for the Colorado River in Utah; the Dinosaur National Monument River Running lottery for the Green and Yampa Rivers in Colorado; the U.S. Forest Service's Rogue River lottery and Four Rivers lottery for the Main Salmon, Middle Fork of the Salmon, Snake (Hells Canyon), and Selway Rivers in the Pacific Northwest. Lastly, while queues are currently used, private river rafting trips in the Grand Canyon were initially allocated by lottery.

Examples of lotteries for harvest rights on public lands and waters are numerous. A fisheries example with international significance was the adoption in 2000 of a lottery to ration harvest rights for elver (eel) to reduce bycatch of the endangered Atlantic Salmon entering Maine waters (Federal Register). Other cases include Moose hunting in Maine, bear hunting in Minnesota, and deer hunting in Connecticut and Virginia. There are lotteries for wild turkey hunts in New Jersey, for duck hunting blinds in Maryland and Ohio, and for bow hunts in Alaska. All western states use lotteries for rationing some or all of their various big-game hunting opportunities; these have histories spanning decades. Numerous examples may also be found outside the United States, including Canada and Greenland.

Lotteries have not been completely ignored in the academic literature on public goods provision. The random allocation of public resources and associated distribution of benefits have been examined in select works. Seneca (1970) demonstrates how Marshallian consumer surplus must be modified to properly measure the benefits from rationed public goods. Mumy and Hanke (1975) consider the situation more generally by examining the quantity of the resource to distribute in order to maximize public benefits, given demand and cost conditions. These early works address allocation at the market level, with individuals not given explicit consideration. More recently, Boyce (1994) considers lottery participation and benefits at the individual level under alternative institutional arrangements (e.g., transferable and non-transferable lotteries).

Complementing the theoretical pieces, empirical analyses of actual decisions made under uncertainty have used laboratories to test various hypotheses about risk preferences (Hey and Orme, 1994) and stated preference surveys to estimate benefits from reduced levels of health risk (Smith and Desvousges, 1987) or under uncertainty about future resource use or quality (Edwards, 1988; Cameron and Englin, 1997). Empirical analyses of participation in real-world lotteries have taken advantage of the purely revealed preference observations provided by state-managed application databases (Loomis, 1982; Coyne and Adamowicz, 1992; Boxall, 1995; Akabua, Adamowicz and Phillips, 1999; Scrogin, Berrens and Bohara, 2000; Buschena, Anderson and Leonard, 2001). Regulation of access through an application and licensing process allows the choices and subsequent outcomes to be observed, in addition to select characteristics of the decision makers, without relying upon samples, surveys or hypothetical questions.

Given their historic use and continued growth, public resource lotteries clearly have some national significance. Since lottery systems typically award no more than one permit per participant and permits are generally non-transferable, the implication is that nonmarket values are associated with lottery-rationed resources. However, methods for estimating of these values are relatively under-investigated in the literature. Of course, lottery systems take a variety of forms and important distinctions between these exist. For example, in some cases individuals confront a single lottery that rations access. In other cases, the system involves multiple, heterogenous lotteries, and participants choose an alternative from a well-defined set (and possibly rank additional preferences as well). Further, some states use "preference points" to influence access probabilities (Buschena, Anderson and Leonard, 2001). Accumulated preference points may be a function of participant characteristics, such as residency status, age, and the number of successive years of participating without being drawn. Given the array of alternative institutional arrangements that may be designed to ration resources, the valuation approach should be tailored to the particular lottery of interest.

The lottery-choice model and resulting welfare measures are presented in the next section. The focus is upon non-transferable lotteries for public access rights, where an individual chooses a single alternative under uncertainty about being granted access, expected gains and expected losses are present, and an awarded license cannot be legally transferred to another party.

III. THE CONCEPTUAL MODEL

Begin by assuming that an individual can choose one lottery from a set of J lotteries and that participants in a given lottery have an equal probability of being drawn. Let S_j represent the fixed quantity of licenses to be allocated in the jth lottery. The term N_j represents the total applicants in the

jth lottery. As the number of applicants is unknown a priori, an individual i forms an expectation of the probability of being drawn, denoted $è_j$.

Individual i derives utility $V(Y_i - P_{j,i}^1, Q_j)$ if drawn in lottery j and utility $V(Y_i - P_{j,i}^0)$ if not drawn. The terms Y_i, $P_{j,i}^1$, and $P_{j,i}^0$ represent income, the access cost associated with an awarded license (e.g., the sum of a participation fee, a license fee and explicit and implicit travel costs), and the costs incurred if not awarded the license (e.g., the participation fee), respectively. We assume that participants are required to submit the entry fee and license fee at the time of application, with the license fee refunded to unsuccessful participants and that successful applicants exercise the rights granted by the license. The term Q_j is a vector of quality attributes associated with the license. Individual i's expected utility of lottery j is then equal to the sum of the probability-weighted utilities:

$$E(L_{j,i}) \quad = \quad è_j\, V(Y_i - P_{j,i}^1, Q_j) \; - \; (1 - è_j)V(Y_i - P_{j,i}^0) \qquad œ\, j\, 0\, J,\, i\, 0\, N \qquad [1]$$

The individual chooses lottery j if its expected utility exceeds that of the other J - 1 lotteries.

Welfare measures for changes in the probability of access or the characteristics of the lottery follow from the expected utility model. An issue that previous studies of public lottery participation have not, we feel, given sufficient attention to either conceptually or empirically is changes in access probabilities. These result indirectly from changes in factors external to the particular lottery system under consideration (e.g., changes in another state's lotteries) or directly from amendments to the system of interest (e.g., imposing quotas on nonresident access or improving habitats). Considering the former and dropping the subscripts, the compensating payment (CS) required to retain the same level of expected utility after a change in the access probability as beforehand is given by:

$$èV(Y - P^1, Q) + (1 - è)V(Y - P^0) \quad = \quad è^*V(Y - P^1 - CS, Q) + (1 - è^*)V(Y - P_j^0 - CS) \qquad [2]$$

Here, only the expected access probability, $\grave{e}_j$, is altered. The superscript on the probability term on the right hand side of [2] denotes the altered level.

Alternatively, welfare may be altered from amendments to the structure of the lottery system or changes in the characteristics of the lotteries. Unlike the above change solely in the expected probability of access, altering the characteristics of the alternatives may affect utility <u>and</u> the probability of being granted access. For example, in the case of lottery-rationed hunting rights, successful herd management or propagation programs may lead to increases in the number of licenses awarded. The number of licenses is a component of the probability of being drawn, yet it may also be a quality attribute, in which case it appears in the vector of quality attributes,

Q_j, in the indirect utility function. Thus, when policy changes affect utility and the access probability the welfare measure is represented:

$$\grave{e}V(Y - P^1, Q) + (1 - \grave{e})V(Y - P^0) \quad = \quad \grave{e}^*V(Y - P^1 - CS, Q^*) - (1 - \grave{e}^*)V(Y - P^0 - CS) \qquad [3]$$

where the superscript * denotes the altered level. In this case both utility and the expected access probability are affected. Note that as the probability of being granted access approaches one, the surplus measure approximates the compensating surplus measure used in non-rationed settings.

We turn next to the empirical analysis of participation in public resource lotteries and the estimation of the expected benefits derived from changes in the lottery system. Because public resource lotteries generally allow an individual to choose a single alternative from a collection with well-defined attributes (e.g., regulations), discrete-choice econometric methods are employed. As suggested in this section, because probabilities of winning and losing accompany lottery participation, expected utility is an appropriate metric for studying lottery choice. Further, welfare analyses of public resource lotteries must account for changes in access probabilities that are likely to result from changes in policy or the structure of the lottery system.

IV. ECONOMETRIC MODELS OF LOTTERY CHOICE, THE DATA, AND ESTIMATION RESULTS

Numerous applications of discrete choice models exist in the nonmarket valuation literature. Statistical approaches for modeling the destination choices of recreationists are largely attributed to early work by McFadden (1973). In the traditional random utility model (RUM) the decision maker's indirect utility function consists of the attributes of the alternatives (and perhaps individual characteristics) and random error. Choice occasions under uncertainty may be modeled in a discrete choice framework by transforming utility into expected utility comprised of expected gains and expected losses through probability weighting.

In laboratory experiments of lottery choice, gains and losses are usually researcher-defined monetary units that are common across participants. In non-transferable lotteries for nonmarket goods, the gain if drawn is individual-specific and unobservable by the researcher and must therefore be expressed as an indirect utility function. The expected gain is equal to the product of the access probability and the utility of an awarded license. We assume the loss if not drawn is equal to the non-refundable participation fee; the expected loss is then equal to the product of the fee and the probability of not being drawn. The sum of the expected gain, expected loss, and random error is the expected utility individual *i* derives from lottery *j*:

$$E(L_{j,i}) \quad = \quad \grave{e}_{j,i}\, X_j^1 \hat{a}_j^1 \quad + \quad (1 - \grave{e}_{j,i}) X_j^0 \hat{a}_j^0 \;+\; g_{j,i} \;\; œ\, j\, \theta\, J \qquad [4]$$

where X_j^1 and X_j^0 are vectors of independent variables specific to the gain and loss, respectively, the term $è_{j,i}$ is the expected access probability, and $â_j^1$ and $â_j^0$ are conformable parameter vectors to be estimated. The stochastic term, $g_{j,i}$, reflects unobservables.

In order to proceed, an assumption must be made about individual expectations of the access probabilities. As Boxall (1995) notes, expected access probabilities may be defined simply as the probability of being drawn in the previous season or in the current season or instead be obtained from an econometric model (Boxall, 1995). Since lotteries are often designed so that the probability of being drawn varies across participants (e.g., lotteries with merit systems or group groups), the econometric approach for generating expected access probabilities will ideally be adopted for choice analyses. However, if the research interest extends to benefits estimation, the econometric approach is appropriate as it provides the means for predicted the necessary changes in access probabilities result from changes in policy.

Because the outcomes of participant choices (i.e., drawn or not drawn) are contained in the data, a latent variables approach is used to generate expected access probabilities or the lotteries contained in individual choice sets. Expectations of the gain and loss comprising the expected utility function are obtained by interacting fitted values of $è_{j,i}$ and $(1 - è_{j,i})$ with the elements in the indirect utility function and the participation fee, respectively. In the second stage of the modeling, the parameters of the expected utility function are estimated, given assumptions about the error distributions. The approach is similar to that used by various authors to construct angler expected catch, a quality attribute used in RUMs of angler fishery choice (e.g., McConnell, Strand, and Blake-Hedges, 1995).[5] The participant's decision process thus is assumed to involve formulating expectations of the probabilities of being drawn and then selecting the utility maximizing lottery.

Differences between our model and those employed in other discrete choice analyses of public lottery participation may now be made explicit.[6] In early work on lottery choice for bighorn sheep hunting licenses, Coyne and Adamowicz (1992) specify simply an indirect utility function, so that the probability of being granted access is implicitly assumed to be equal to one in the choice and welfare analyses. Boxall (1995) recognizes the uncertain nature of public resource lottery choice. An expected utility model is developed for the lottery choice occasion, however, the probability of being granted access is represented by the previous season's probability and is held constant across policy settings. Further, the deterministic component in the econometric model reflects only expected gains. Akabua, Adamowicz and Phillips (1999) examine the performance of Boxall's model relative to an expected utility model used by Rouwendal (1989) in a study of housing choice. Access probabilities are again assumed constant across policy settings and expected losses are excluded.

When explicit and implicit costs are incurred by participants, lottery choice models that exclude expected losses may be mis-specified and suffer from omitted variables bias. But most importantly, because static access probabilities are an unlikely result of changes in the characteristics of goods rationed by lottery or the underlying institutional arrangement, welfare analyses must be amended appropriately. Our approach for generating the expected access probabilities provides the means for predicting the necessary changes in the access probabilities resulting from altered policy.

The Data

The public resource lotteries we consider are the 1996-97 season drawings for New Mexico

(NM) elk harvest rights. The NM big-game lottery system was adopted in 1933 due to the over-harvest of elk. The current system rations licenses to hunt elk, Rocky Mountain and desert bighorn sheep, the exotic transplants ibex and oryx, javelina (wild pig), antelope and deer.

During the season considered, the 215 lotteries for elk licenses attracted more than 37,000 applicants for about 23,000 licenses. The lotteries differ spatially in time and geographic location, in the types of equipment that may be used, and in various regulatory and quality characteristics. Participation requires submission with the application of a six dollar entry fee and a license fee that varies by bag-limit; the license fee is refunded to unsuccessful applicants. An individual may submit only one application to hunt elk annually, and unsuccessful applicants must wait until the following season to re-apply. The entire collection of 215 elk-hunt lotteries and 29,560 resident participants are used to model the probability of access, and the 136 rifle elk-hunt lotteries and 18,708 resident participants are used in the second stage, choice model.[7]

Table 1 reports summary statistics on the independent variables included in the access probability and choice models. The lotteries award on average approximately 112 licenses, and about fifty-percent of applicants were drawn in the previous season on average (Past Probability). Access cost is constructed as the sum of the six dollar participation fee, the license fee, and round trip road miles between the applicant's zip code and the approximate center of the geographic boundary of the hunt (i.e., the game unit).[8] The loss if not drawn is assumed to be equal to the application fee. While the application fee is constant across alternatives, variation is induced and expected loss generated when the fee is interacted with the probability of not being drawn.

Variables reflecting lottery characteristics (e.g., regulations and hunt quality) are constructed from information provided to participants in the application book. The variables Licenses and Probability measure the absolute and relative numbers of licenses that are awarded, respectively. The former is presumed to reflect herd sizes and qualities; the latter is a relative congestion measure. The variable Harvest is the percentage of hunters who harvested an elk in the previous season, and Bull and Antlerless are harvest regulations (i.e., bag-limits). Finally, variables for hunt time (Opening, Holiday and Late) and location (NE, SW and SE) are included.

Estimation Results

At the first stage the expected access probabilities are obtained for the alternative lotteries by modeling the observed outcomes (drawn or not drawn). Four models are examined: the standard and skewed logit (Nagler, 1994) models and the standard and heteroscedastic probit models. Included as an explanatory variable in all models is the probability of being granted access in the previous season, Past Probability. Included in heteroscedastic probit variance term are the two components defining Past Probability: Applicants and Licenses.

Consider first the estimation results for the expected access probability models (Table 2). In all cases Past Probability is highly significant. The generalized logit and probit models outperform their restricted counterparts. Considering the heteroscedastic probit, the null of probit (Ho: $\hat{a}_{Applicants} = \hat{a}_{Licenses} = 0$) is rejected at the 0.01 level with a likelihood ratio test. And with the skewed logit model, the null of logit (Ho: $\acute{a} = 1$) is also rejected at the 0.01 level with a simple t-test. Comparing goodness-of-fit measures for the two generalized models, the heteroscedastic probit slightly outperforms the skewed logit. Thus, the heteroscedastic probit is chosen to generate the expected access probabilities needed for estimation of the REUMs.

Lottery choice is modeled at the second stage conditional upon the first stage estimates. Given the large number of lotteries from which to choose (136), unique choice sets are generated for each of the 18,708 applicants by random draws (e.g., Parsons and Kealy, 1992). To assess the robustness of the REUM to the choice set definition, sets comprised of J = 25, 50, 75 and 100 lotteries are generated from the full set of 136 rifle hunts. For comparison naive RUMs, which do not account for the probability of access, are also estimated. In all cases McFadden's conditional logit model is estimated.[9]

For both the REUM and RUM specifications, the models are robust to the definition of the choice set as gauged by the parameter estimates, and in nearly all cases the parameter estimates are highly significant (Table 3). Overall, the fits of the REUMs are nearly identical to those of the naive models (RUMs). Despite the estimates being rather indistinguishable in many cases between the REUM and RUM (e.g., Bull, Antlerless, Holiday and Harvest), it is important to note that the variables in the REUM involve interactions with the expected access probabilities. Finally, in all cases the expected loss is found to have a significantly negative relation to the choice probabilities, suggesting that omitted variables bias may be present in models of choice under uncertainty that include only expected gains. However, the magnitudes of the estimated coefficient may be attributed to the relatively small sizes of the outcomes taken by the variable.

Considering the performance of the REUM across alternative definitions of the choice set and relative to a traditional RUM, a natural question arises regarding the welfare estimates produced by the model relative the RUM. We address this issue in the proceeding section.

V. SIMULATIONS AND COMPENSATING SURPLUS ESTIMATES

In addition to analyzing recreational lottery choice, the REUM may be used to measure welfare changes resulting from amendments to lottery systems. Similarly to the choice analysis, the probability of being granted access must be accounted for in welfare analyses, and in particular, the changes in the access probabilities that result from changes in policy, the structure of the lottery system, or factors external to the particular system of interest. The estimated heteroscedastic probit model is to predict the changes in the probability of access (see Table 2).

Welfare estimates are obtained for changes individually and jointly in the access probabilities and utility function. First, welfare is estimated for changes in the access probability that result from some external, participation-altering event (represented by expression 2). For example, the imposition of a quota on the proportion of licenses to award a particular group of participants in one state (e.g., nonresidents) may lead to changes in participation in the lottery system of interest. Considering the empirical specification of the REUM, the expected access probabilities are altered but not the utility function. The scenarios considered are ten percent and twenty-five percent reductions in the number of lottery participants.

Second, welfare changes are estimated when the access probabilities and utility are jointly altered from a change in the lottery system (represented by expression 3). For example, successful herd restoration or propagation efforts often lead wildlife biologists to advise a change in the number of licenses to distribute. The number of available licenses influences the probability of access, yet it also serves as an attribute of a given lottery. Compensating surplus is estimated for ten and twenty-five percent increases in the number of awarded licenses, assuming that a change in the number of licenses is not met by a change in the number of participants.

Third, welfare changes are estimated for the situation where a change in a quality attribute affects utility but not the access probability. This third situation, with access probabilities assumed constant, is similar to Boxall's (1995) approach. The differences between the approaches rest in the definition of the access probabilities and the inclusion of expected losses in the definition of expected utility. The scenarios considered are ten and twenty-five percent increases in the harvest rate.

In all cases, the compensating surplus for a change in alternative j from the status quo (0) to a new state (1) is calculated as:

$$CS = -\frac{1}{MU_Y}\left[\ln\sum_{i=1}^{J^*} e^{E(L_j)^0} - \ln\sum_{i=1}^{J^*} e^{E(L_j)^1}\right] \qquad [5]$$

The terms $E(L_j)^0$ and $E(L_j)^1$ denote the estimated expected utilities before and after a change in a characteristic of the lottery, respectively, and the term J^* denotes the full set of 136 alternatives. The absolute value of MU_Y is the marginal utility of income, which is obtained from a transformation of the access cost variable in the estimated model. Like with (3), the empirical surplus measure converges on that used in non-rationed settings when the probability of being drawn approaches one. For comparison, welfare estimates from the RUM are also reported.

Overall, the compensating surplus estimates are robust to the number of alternatives contained in applicant choice sets for the REUMs and RUMs (Table 4). While others have found welfare estimates to be sensitive to choice set size, the numbers of decision makers considered were small relative to the number considered here.

Consider first the reductions in the number of participants decreases. In this scenario, expected utility is altered due to the resulting change in the expected access probability. Because expected access probabilities do not enter the RUM, welfare gains for increased access probabilities cannot even be calculated. Whereas for the REUM, the compensating surplus for ten and twenty-five percent reductions in the number of participants is estimated to be about thirty dollars. In the second scenario the number of awarded licenses increases, altering both the access probability and utility. The results from the REUM suggest that the compensating surplus for a twenty-five percent increase in the number of licenses is about 140 dollars; the RUM estimates are only about one-third of the REUM estimates. As the numbers of licenses to award are generally determined by wildlife biologists, license increases such as these may result from positive shocks to herd populations. Finally, in the third scenario, the quality changes affect utility but not the expected access probability. In both cases, the REUM generated surplus estimates are exceeded by the RUM estimates.

To summarize, for recreational choices involving uncertainty, the REUM is theoretically preferred to the RUM. But a legitimate question is whether the distinction is likely to be important empirically. The results from this study of recreational lottery participation indicate that the REUM versus RUM distinction has greater impact on estimated surplus values than varying the size of the choice set.[10]

VI. CONCLUSIONS

Discrete choice models of individual behavior have emerged as the preferred approach for estimating consumptive use values for changes in environmental quality. However, pressures on natural resource stocks coupled with equity concerns have influenced the adoption of lotteries for rationing numerous access opportunities. Considering this, and recognizing that public resource lotteries randomly allocate nonmarket goods across participants, discrete choice models based upon the assumption that individuals maximize utility, rather than expected utility, may be inappropriate for analyzing lottery choice and estimating welfare changes.

Extending the sparse literature (Boxall, 1995; Akabua, Adamowicz and Phillips, 1999), the present study develops and employs a random expected utility model to the case of public resource lotteries. A key contribution of the analysis is the construction of an expected probability of being granted access. Observed outcomes (drawn or not drawn) are modeled in order to generate expected access probabilities for the alternatives in participant choice sets. Welfare estimates are obtained from simulated policy changes that affect, both individually and jointly, the access probability and indirect utility. To illustrate the importance of the random expected utility model, although estimated compensating surplus is robust to choice set size in our case study, failure to account for changes in access probabilities is found to lead to large differences in the welfare estimates.

In closing, as an institutional arrangement for rationing resource stocks and access rights on public lands and waterways, lotteries are operated in most (if not every) state of the country. Despite some recent contributions we argue that there is still a significant gap in the collective knowledge about public resource lotteries, in general, and recreational access lotteries, in particular. Given the prevalence of, and growth in, lotteries for rationing nonmarket goods, and that contributions in this area are relatively limited, continued research efforts are clearly warranted.

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Notes

1. Although it is common to refer recreational hunting and fishing opportunities as privileges for license holders, we adopt the terminology that recreational lotteries allocate access <u>rights</u> rather than <u>privileges</u>. Following (Bromley, 1989, pp. 44-46), given the social nature of institutional arrangements, a right can be distinguished from a privilege in that it imposes a correlate duty on others within the collective to observe the right (or face sanction). Whereas, a privilege has no such correlate duty, and others in the collective have "no rights" (i.e., to block some action). Of all hunters that apply for a permit in a lottery, a winner obtains the right to a potential benefit (access to a particular hunting site), and others have the correlate duty to observe that right (and not hunt at the site). This can be contrasted with non-rationed hunting and fishing opportunities, where any license holder has a general access privilege to open areas, and others have no right to block. While poaching may occur under either arrangement, to some degree the difference between rights versus privileges is an active versus passive distinction.

2. Non-recreational examples include the Federal Communications Commission rationing of licenses for unserved cellular areas and Bureau of Land Management programs for re-locating wild horses and burros from public to private lands. The Bureau has also used lotteries as part of the process for allocating coalbed methane gas leases.

3. As an angler does not typically visit every site in the choice set he or she is assumed to face, expected catch at each site is obtained by modeling angler reported catch. The question of whether or not to jointly or sequentially estimate angler expected catch and destination choice has been given

considerable recent attention (e.g., Morey and Waldman, 1998; Train, McFadden and Johnson, 2000; Morey and Waldman, 2000). Biases are associated with both approaches and a preferred method may be case-specific. In the present study we use the sequential approach and leave the joint model to future research.

4. For brevity, we limit our discussion to the discrete choice literature, yet aggregate models have also been used in lottery demand and welfare analyses (e.g., Loomis, 1982; Scrogin, Berrens and Bohara, 2000; Buschena, Anderson and Leonard, 2001).

5. The remaining seventy-nine elk hunts are divided between muzzleloader hunts (33), bow hunts (43) and hunts for the physically impaired (3). In all cases, resident and nonresident applicants faced equal probabilities of being drawn.

6. Round-trip road-mileage estimates were constructed from the Zipfip program (Hellerstein, Woo, McCollum and Donnelly, 1993).

7. Estimation was performed with Stata version 7.0 on a Dell Precision 530 Workstation.

8. The issue of appropriate choice set definition has been the topic of considerable recent discussion and investigation. For a recent review see Smith (2000, p. 366).

Table 1. Variable Definitions and Summary Statistics

Variable	Definition	Mean	Standard Deviation
Ln(Access Cost)	Natural logarithm of the $6 participation fee + license fee + $0.325*miles	5.27	0.56
Ln(Loss)	Natural logarithm of the $6 participation fee	1.79	---
Licenses	Number of rationed licenses in 1996-97 season	112.59	110.35
Past Probability	Ratio of Licenses to 1995-96 season applicants	0.51	0.32
Harvest	Ratio of harvest to hunters for 1995 season	0.33	0.26
Quality	1 if hunt designated as Quality; 0 otherwise	0.13	0.33
Bull	1 if hunt for bull elk; 0 otherwise	0.54	0.50
Antlerless	1 if hunt for antlerless elk; 0 otherwise	0.39	0.49
Opening	1 if opening week hunt; 0 otherwise	0.05	0.22
Holiday	1 if hunt is held over a holiday; 0 otherwise	0.04	0.21

Table 1 continued

Late	1 if late-season (March) hunt; 0 otherwise	0.01	0.12
NE	1 if hunt is in northeast NM; 0 otherwise	0.27	0.45
SW	1 if hunt is in southwest NM; 0 otherwise	0.23	0.42
SE	1 if hunt is in southeast NM; 0 otherwise	0.03	0.17

Table 2. Estimated Expected Access Probability Models

		Heteroscedastic		
N = 29,560	Probit	Probit	Logit	Skewed Logit
Past Probability	1.66***	0.98***	2.76	6.05***
	(0.03)	(0.03)	(0.05)	(0.72)
Constant	-0.59***	-0.35***	-0.99	0.15***
	(0.02)	(0.01)	(0.03)	(0.15)
Ln(ó^2)				
Licenses	—	-0.003***	—	—
		(0.000)		
Applicants	—	0.00001	—	—
		(0.0001)		
Ln(á)	—	—	—	-1.21***
				(0.14)
Log-Likelihood	-18,024	-17,704	-18,009	-17,975
Pseudo R^2	0.09	0.11	0.09	0.10

Note: *** denotes significance at the 1% level.

Table 3. Conditional Logit Estimates of Lottery Choice Models

N = 18,708	REUM				RUM			
Variable	J = 25	J = 50	J = 75	J = 100	J = 25	J = 50	J = 75	J = 100
Ln(Access Cost)	-4.31***	-4.35***	-4.36***	-4.38***	-2.56***	-2.62***	-2.63***	-2.65***
	(0.04)	(0.04)	(0.04)	(0.04)	(0.03)	(0.02)	(0.02)	(0.02)
Ln(Loss)	-13.94***	-14.45***	-14.58***	-14.79***	----	----	----	----
	(0.34)	(0.33)	(0.33)	(0.33)				
Licenses	0.01***	0.01***	0.01***	0.01***	0.01***	0.01***	0.01***	0.01***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Probability	-7.45***	-8.13***	-8.33***	-8.58***	----	----	----	----
	(0.47)	(0.45)	(0.45)	(0.45)				
Harvest	0.74***	0.80***	0.82***	0.82***	0.77***	0.80***	0.82***	0.81***
	(0.07)	(0.07)	(0.07)	(0.07)	(0.04)	(0.04)	(0.04)	(0.04)
NE	0.11**	0.12**	0.14***	0.14***	-0.08***	-0.07***	-0.07***	-0.06**
	(0.05)	(0.05)	(0.05)	(0.05)	(0.03)	(0.03)	(0.03)	(0.03)
SW	1.93***	1.97***	2.00***	2.01***	1.02***	1.05***	1.06***	1.07***
	(0.05)	(0.04)	(0.04)	(0.04)	(0.02)	(0.02)	(0.02)	(0.02)

SE	2.17***	2.31***	2.35***	2.40***	1.27***	1.35***	1.38***	1.40***
	(0.08)	(0.08)	(0.07)	(0.07)	(0.04)	(0.04)	(0.04)	(0.04)
Quality	-0.48***	-0.52***	-0.53***	-0.52***	0.06*	0.04	0.04	0.05
	(0.08)	(0.08)	(0.08)	(0.08)	(0.03)	(0.03)	(0.03)	(0.03)
Bull	0.73***	0.71***	0.72***	0.70***	0.77***	0.78***	0.78***	0.78***
	(0.06)	(0.06)	(0.06)	(0.06)	(0.04)	(0.04)	(0.04)	(0.04)
Antlerless	0.14**	0.09	0.10	0.09	0.39***	0.37***	0.37***	0.37***
	(0.07)	(0.06)	(0.06)	(0.06)	(0.04)	(0.04)	(0.04)	(0.04)
Opening	0.41***	0.46***	0.45***	0.46***	0.21***	0.23***	0.22***	0.22***
	(0.07)	(0.07)	(0.07)	(0.07)	(0.03)	(0.03)	(0.03)	(0.03)
Holiday	-0.28***	-0.27***	-0.28***	-0.24**	-0.27***	-0.27***	-0.28***	-0.26***
	(0.11)	(0.10)	(0.10)	(0.10)	(0.05)	(0.05)	(0.05)	(0.05)
Late	3.67***	3.71***	3.71***	3.72***	1.64***	1.66***	1.67***	1.67***
	(0.09)	(0.08)	(0.08)	(0.08)	(0.05)	(0.05)	(0.05)	(0.05)
N	467,700	935,400	1,403,100	1,870,800	467,700	935,400	1,403,100	1,870,800
Ln(likelihood)	-46,245	-58,599	-65,966	-71,222	-45,912	-58,168	-65,520	-70,738
Pseudo R^2	0.23	0.20	0.18	0.17	0.24	0.21	0.19	0.18

Table 3 continued

Note: The term J refers to the number of randomly drawn alternatives contained in participant choice sets. ***, **, and ** denote significance at the 1%, 5%, and 10% level, respectively.

Table 4. Mean Compensating Surplus for Changes to the Lottery System

N = 18,708	REUM J = 25	REUM J = 50	REUM J = 75	REUM J = 100	RUM J = 25	RUM J = 50	RUM J = 75	RUM J = 100
Scenario:								
Decrease in Applicants								
Ten percent	$7.42	$7.87	$7.97	$8.20	----	----	----	----
	(2.54)	(2.50)	(2.49)	(2.49)				
Twenty-five percent	21.87	23.25	23.57	24.29	----	----	----	----
	(7.11)	(6.99)	(6.97)	(6.98)				
Increase in Licenses								
Ten percent	30.51	30.61	30.63	30.91	$11.58	$11.08	$10.98	$10.86
	(8.71)	(8.38)	(8.31)	(8.23)	(2.68)	(2.57)	(2.55)	(2.53)

Table 4 Continued

Twenty-five percent	97.01	97.47	97.63	98.58	29.96	28.67	28.41	28.08
	(23.07)	(22.62)	(22.55)	(22.52)	(6.83)	(6.55)	(6.50)	(6.42)
Increase in Harvest Rate								
Ten percent	3.07	3.26	3.35	3.31	5.68	5.86	5.93	5.86
	(0.78)	(0.84)	(0.86)	(0.86)	(1.60)	(1.68)	(1.71)	(1.71)
Twenty-five percent	5.04	5.34	5.49	5.42	9.40	9.70	9.82	9.71
	(1.04)	(1.10)	(1.13)	(1.12)	(1.89)	(1.96)	(1.98)	(1.97)

Note: The term J refers to the number of randomly drawn alternatives contained in participant choice sets. Numbers in parentheses are standard deviations of estimated willingness to pay.