Title: Rationed Access and Welfare: Case of Public Resource Lotteries

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Proposed Running Head: Public Resource Lotteries

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Abstract

Pressures on natural resource stocks and habitats 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 the modeling is the estimation of individual-specific expected access-probabilities. In the application we model the discrete choices of more than 18,000 participants in a lottery system for harvest rights. Welfare estimates are obtained from simulated policy changes affecting individually and jointly the access probability and indirect utility.

Keywords: Lotteries, access, discrete choice

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 US and elsewhere. Equity concerns yield lotteries as the mechanism commonly preferred by the public as they ration independently of income. For many nonmarket analyses, lottery systems remain a largely untapped source of revealed preference data and one that is not dependent on samples, surveys or hypothetical questions.

Regardless of the particular good being rationed, a common characteristic of lottery participation is that it involves discrete choice. If a lottery is used to ration 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 choice 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-level models have been developed and employed for lottery demand and welfare analysis (e.g., Nickerson, 1990; Scrogin, Berrens and Bohara, 2000; Buschena, Anderson and Leonard, 2001), the unit of analysis will ideally be the individual. Yet discrete choice approaches for modeling lottery participation are relatively under-investigated (Boxall, 1995; Akabua, Adamowicz and Phillips, 1999).

What makes lottery choice behavior particularly interesting is that unlike auctions, queues and merit systems, lotteries randomly allocate resources. As such, individuals face uncertainty in participating, and the ex ante, subjective probability of being granted access may deviate from the realized, ex post probability. Further, changes in access probabilities may result from amended policy. Thus, when access is rationed, discrete choice analyses and benefits estimation must be amended appropriately. Building upon and significantly extending the sparse, existing literature, the present study develops a two stage, random *expected* utility model (REUM) for lottery demand analysis. Particular attention is given to benefits estimation.

Key to analyses of gambling-related activities (at an individual or aggregate level), such as lottery participation, is the construction of an ex ante, subjective probability of winning. Drawing upon select literature on gambling behavior, we estimate individual-specific access probabilities by modeling the observed outcomes of the lottery (i.e., being drawn or not) of more than 29,500 individuals over 215 lotteries for New Mexico (NM) big-game harvest rights. Lottery choices made by a large subset of these participants (approximately 19,000) are then modeled. The approach is similar to recently proposed models of angler expected catch and site choice, where the former are used to generate an expectation of catch at each site. For additional comparison, a RUM (which ignores the probability of access) is estimated.

The paper is structured as follows. Section II provides background information on the increasing importance of lotteries in rationing public resources and reviews the literature on resource lotteries and benefits estimation under uncertainty. In section III an expected utility model is developed from which associated welfare measures under uncertainty follow. The empirical model, data and estimation results are presented in section IV, and section V explores the welfare effects of amendments to the lottery system. Welfare estimates are obtained from simulated policy changes affecting individually and jointly the access probability and utility function. Section VI concludes.

II. Background: Lotteries for Rationing Scarce Public Resources

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

Prominent river rafting lottery examples 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 US Forest Service's Rogue River lottery and "Four Rivers" lottery for the Main Salmon, Middle Fork of the Salmon,

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[1] Federal, 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.

Snake (Hells Canyon), and Selway Rivers in the Pacific Northwest. Recreational boat docking and launching privileges on Ohio waters are lottery rationed. Lastly, while queues are currently used, Grand Canyon rafting opportunities have also been allocated by lottery (Loomis, 1982).

Examples of lotteries for harvest privileges on public lands and waters are numerous. A recent fishing example 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; deer hunting in Connecticut and at selected state parks in Virginia; waterfowl hunting at various wildlife management areas in Louisiana; and waterfowl hunting at selected lakes of the City of San Diego, California. There are special lotteries for wild turkey hunts in New Jersey, for allocating selected blinds for duck hunting on Ohio lakes, and bow hunts for Alaskan big-game. All western states use lotteries for rationing some or all of their various big-game hunting opportunities; these have histories spanning decades (e.g., Oregon and New Mexico). There are also numerous examples from outside the US, including Canada and Greenland. Recent lottery adoptions include the introduction of a state-wide deer hunting lottery in Utah for 2000 (Wharton, 1999) and limited cougar hunts in Washington for 2000 (Associated Press, 2000). Lotteries (but primarily auctions) are also held by the Foundation for North American Wildsheep and Rocky Mountain Elk Foundation to distribute hunting privileges; the bulk of the generated revenues are returned to the states to fund herd restoration and propagation efforts.

Lotteries have not been completely ignored in the academic literature on public goods provision. The random allocation of public resources and the resulting distribution of benefits have been examined in select theoretical and empirical 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 ration 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 welfare at the individual level in an expected utility framework; participation and benefits under alternative lottery systems are examined (e.g., transferable and non-transferable lotteries).

Complementing the theoretical pieces, empirical analyses of lottery-related behavior have used laboratories to test various hypotheses about choice under uncertainty (e.g., Hey and Orme (1994) but without explicitly considering public goods), and stated preference surveys to estimate benefits from reductions in the level of risk or uncertainty (Smith and Desvousges, 1987). The select empirical analyses of actual lottery participation 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). These offer a key means for identifying users (and non-users) without relying upon samples, surveys or hypothetical questions. Regulation of access through an application and licensing process allows both the choices and subsequent outcomes to be observed, in addition to select characteristics of the decision makers.

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 to a participant (or party) and this permit is generally not transferable, the implication is that there is some nonmarket value associated with the opportunity. However, the elicitation and estimation of these values are relatively under-investigated in the literature. Of course, public resource lotteries come in many different forms and important distinctions between these exist.[2] For example, in some cases the system is comprised of 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). Thus, the valuation approach should be tailored to the type of lottery under consideration.

In the next section we pose a lottery-choice model at the individual level using an expected utility framework. The focus is upon nontransferable lotteries for public access rights, where an individual chooses a discrete alternative under uncertainty and an awarded right 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 alternatives and that participants in a given lottery have an equal probability of being drawn (i.e., being granted access to a stock). Let S_j represent the fixed quantity of licenses to be issued in lottery j,

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[2] For example, in some states systems of "preference points" are often used to influence the probability a given applicant is granted access (Akabua, Adamowicz and Phillips, 1999; 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 and not being drawn. Amended points structures may alter the success probabilities.

where a license defines the access right (e.g., the opportunity to harvest a species). The term N_j represents the total applicants for the jth lottery. Thus, the ex post probability of being drawn is S_j / N_j, denoted θ_j. This ex post value is not observable *a priori* as the number of participants is unknown. Hence, individual i faces a subjective, ex ante probability that may deviate from the true value. Assume for convenience that the ex ante and ex post probabilities are equal.[3] Individual i derives utility of $V_{j,i}(Y_i , P_{j,i}^1, Q_j)$ if drawn in the jth lottery and disutility of $-V_{j,i}(Y_i , P_{j,i}^0)$ if not drawn. The terms Y_i, $P_{j,i}^1$, and $P_{j,i}^0$ represent income, the cost incurred if awarded a license (e.g., the sum of a participation fee, a license fee and explicit and implicit travel costs), and the cost incurred if not awarded a license (e.g., the participation fee), respectively. The term Q_j is a vector of quality attributes for the jth alternative. The expected utility of lottery j is then equal to the sum of the probability-weighted utilities:

$$E(L_{j,i}) = \theta_j V_{j,i}(Y_i , P_{j,i}^1, Q_j) - (1 - \theta_j)V_{j,i}(Y_i , P_{j,i}^0) \qquad \forall j \in J \tag{1}$$

The individual chooses lottery j if its expected utility exceeds that of all other lotteries.

Individual welfare measures follow from the lottery choice 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 species' habitats). Considering the former and

[3] Deviations between subjective and objective probabilities of gambles have been given considerable attention. Of interest are the long-shot anomaly and gambler tendency to over-bet on objectively low-probability events (e.g., Ali, 1977; Golec and Tamarkin, 1998).

dropping the individual-specific subscripts, the payment (CS) required to retain the same level of expected utility after an increase in the access probability as beforehand is given by:

$$(2) \quad \theta_j^0 V_j(Y, P_j^1, Q_j) - (1 - \theta_j^0)V_j(Y, P_j^0) \quad = \quad \theta_j^1 V_j(Y - CS , P_j^1 , Q_j) - (1 - \theta_j^1)V_j(Y - CS, P_j^0)$$

Here, only the access probability, θ_j, is altered. The superscripts 0 and 1 on the probability terms refer to the status quo and altered level, respectively. Expression (2) is equivalent to the measure of option value in Smith and Desvousges (1987). A payment of CS (the compensating surplus) is required to leave the individual indifferent between the access probability change and the status quo.

Additionally, welfare may be directly altered from amendments to the lottery system or changes in the characteristics of the alternatives. Unlike the above change strictly in the probability of being granted access, altering the characteristics of the alternatives may affect both the utility function and the probability of being granted access. For example, in the case of lottery-rationed hunting privileges, successful herd management or propagation programs may lead to increases in the number of licenses awarded in some or all of the lotteries. 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 Q_j in the indirect utility function. Thus, in the case where the policy change affects utility and the access probability the welfare measure is represented:

$$(3) \quad \theta_j^0 V_j(Y, P_j^1, Q_j^0) - (1 - \theta_j^0)V_j(Y, P_j^0) \quad = \quad \theta_j^1 V_j(Y - CS, P_j^1, Q_j^1) - (1 - \theta_j^1)V_j(Y - CS, P_j^0)$$

where Q_j^0 and Q_j^1 refer to the status quo and the altered level, respectively. In this case both the attribute vector and the access probability are affected.

We turn now to the empirical analysis of participation in public resource lotteries and the estimation of the associated expected benefits derived from the rationed access opportunities.

Because public resource lotteries generally allow the public to choose a single alternative from a well-defined collection, discrete-choice econometric methods are employed for analyzing lottery participation and estimating changes in individual welfare. As argued in this section, access probabilities are relevant to the choice of lottery. Further, welfare analyses of lottery systems must account for the access probabilities and, in particular, changes in these probabilities that may result from amendments to the lottery system.

IV. Econometric Models of Lottery Choice, the Data, and Estimation Results

Numerous applications of discrete choice models exist in the recreation demand literature. The statistical approaches that have been developed and employed are largely attributed to early work by McFadden (1973). In the traditional random utility model (RUM) of destination choice, the decision maker's indirect utility is generally expressed as a function of the attributes of the alternative, individual characteristics and random error. The lottery choice occasion may be modeled in a discrete choice framework by transforming the utility function into an expected utility function, in the process obtaining expected gain and loss components.

In laboratory experiments of lottery choice, gains and losses have generally been stated dollar amounts and thus are observed by the researcher (e.g., Hey and Orme, 1994). In non-transferable lotteries for nonmarket goods, the gain if granted access is individual-specific and unobservable and must therefore be expressed as an indirect utility function; the expected gain is then equal to the product of the indirect utility function and the access probability. We assume the loss if not drawn is equal to the participation fee; the expected loss is then equal to the product of the fee and the access probability. The sum of the expected gain and loss is the expected (indirect) utility of the jth lottery:

$$E(L_{j,i}) = \beta_j^1 \theta_{j,i} X_j^1 + \beta_j^0 (1 - \theta_{j,i}) X_j^0 + \varepsilon_{j,i} \qquad \forall j \in J \tag{4}$$

The two deterministic components consist of the expected gain and expected loss; X_j^1 and X_j^0 are, respectively, independent variables specific to the expected gain and the expected loss. The term $\theta_{j,i}$ is the individual-specific expected probability of being granted access, and β_j^1 and β_j^0 are parameter vectors to be estimated. The stochastic term, $\varepsilon_{j,i}$, reflects unobservables.

Expected access probabilities, $\theta_{j,i}$, are obtained at the first stage by modeling the binary outcomes (drawn or not drawn) from a separate or over-lapping lottery participant dataset. The approach is similar to that used by various authors to construct expected catch, a quality attribute used in random utility models of angler destination choice (e.g., McConnell, Strand, and Blake-Hedges, 1995).[4] The expected gain and loss components in $E(L_{j,i})$ are then obtained by interacting $\theta_{j,i}$ and $(1 - \theta_{j,i})$ with the elements in the indirect utility function and the participation fee, respectively. In the second stage, the parameters of the expected utility function are estimated, given an assumption about the distribution of the errors. Because the regressors are interaction variables, care should be exercised when interpreting the results. Parameter estimates

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[4] In particular, as an angler does not typically visit every site in his or her choice set, 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.

for both stages of the modeling are obtained by maximum likelihood.

The differences between this and the select models that have been employed in other discrete choice analyses of public lottery participation can now be made explicit.[5] In early work on lottery choice for bighorn sheep hunting licenses, Coyne and Adamowicz (1992) specify simply an indirect utility function, and the probability of being granted access is assumed not to exist (or is constant across alternatives) in the choice and welfare analyses. Boxall (1995) recognizes the uncertain nature of the participation decision in public resource lotteries. An expected utility model is developed for lottery choice occasions, however, the deterministic component in the econometric model reflects purely the expected gain. Further, the probability of being granted access, represented by the previous season's probability, is assumed constant across policy settings. 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. Expected losses are again excluded and access probabilities assumed constant across policy settings and individuals.

Assuming explicit and implicit costs are incurred with participation, expected losses should be included in the empirical model. Whether or not they contribute statistically to the model can readily be tested. Further, and most importantly, because static access probabilities are an unlikely result of changes made to a lottery system, welfare analyses must be amended appropriately. The process for generating individual expected access probabilities, $\theta_{j,i}$ $\forall j \in J$,

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[5] 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).

provides the means for predicting changes in the probabilities 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 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 type of equipment that may be used, and in a variety of additional regulatory and quality characteristics. Variables reflecting these and participant characteristics were constructed. We restrict our analysis at the access-probability stage of the modeling to the 29,560 resident participants and at the choice stage to the 136 rifle hunts and associated 18,708 resident participants.[6]

[6] The remaining seventy-nine elk hunts are divided between muzzleloader hunts (33), bow hunts (43) and hunts for the physically impaired (3). In the season examined, resident and nonresident applicants faced equal probabilities of being drawn. However, the subsequent season marked a historic event in NM game policy as quotas were imposed on the number licenses that would be awarded to nonresidents in the lotteries for several species, including elk. The quotas guarantee residents seventy-eight percent of the licenses. Interestingly, resident participation increased by more than fifty-percent subsequent to the imposition of the quotas, reducing the probability a given resident was drawn in the majority of lotteries.

Table I reports summary statistics on the independent variables included in the access probability and choice models. Applicants are largely male and forty years of age on average. The average lottery awards about 112 licenses; about fifty-percent of applicants were drawn in the previous season in the average lottery. Travel cost if drawn is constructed as the sum of the six dollar participation fee, the license fee (which varies by bag limit), and round trip road miles between the applicant's zip code and the center of the geographic boundary of the hunt (i.e., the *game unit*).[7] The loss if not drawn is assumed to be equal to the participation fee. While the fee is constant across alternatives, variation is induced when interacted with the probability of not being drawn to form expected loss. The access cost and loss variables are converted to natural logarithms. The remaining variables are constructed from information reported in the application book. The variables Licenses and Probability reflect 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 measure of congestion. Harvest is the percentage of hunters who harvested an elk from 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.

The Access Probability Models

Given that the lottery participant data reports the outcomes (drawn or not drawn), a binary model is used to estimate individual-specific access probabilities. The estimates from this first

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

stage of the modeling are then used to generate individual-specific access probabilities for the alternatives in participant choice sets. Further, for the welfare analysis it provides the means by which to predict access probabilities subsequent to changes in the lottery system. Four binary models of the probability of being granted access are evaluated. These are the standard logit and probit models and generalizations of these: the heteroscedastic probit and the skewed logit (or "scobit") model (Nagler, 1994).

Included in the model are the individual-specific variables Age and Gender and the previous season's probability of being granted access, Probability. The components of Probability (Applicants and Licenses) are included in the variance term of the heteroscedastic probit. Because the outcomes in a given lottery are random, the fit of a model of lottery success might be expected to be relatively poor with a small number of alternatives. However, given a large number of lotteries (136) and variation in participant characteristics, modeling the outcomes may be revealing about those who are successful and those who are not. But most importantly, the model allows predictions to be made about changes in the access probabilities due to altered numbers of awarded licenses or participants.

As gauged by the goodness-of-fit measures, the models perform relatively well in predicting the outcomes despite the randomness of outcomes in a given lottery (Table II). Interestingly, in all cases the individual-specific variables are statistically significant.[8] The probability of being granted access increases at a decreasing rate with age. Also, male applicants

[8] Individual characteristics may also be relevant for modeling "preference points" accumulated over seasons as with the aggregate, hedonic approach used by Buschena, Anderson and Leonard (2001).

are more likely to be drawn than female applicants. In all cases the previous season access probability is positively and significantly related to the current season access probability.

Results indicate that the generalized logit and probit models outperform the restricted models. Considering the variance term in the heteroscedastic probit, although only the coefficient on Licenses is significant, the null of probit (Ho: $\beta_{Applicants} = \beta_{Licenses} = 0$) is rejected at the 0.01 level with a likelihood ratio test. In the skewed logit case, the null of logit (Ho: $\alpha = 1$) is also rejected at the 0.01 level with a simple t-test. Comparing goodness-of-fit measures for the two generalized models, we find the heteroscedastic probit to outperform the skewed logit model. Thus, the heteroscedastic probit is chosen to generate individual-specific expected access probabilities for the alternatives in the choice sets.

The Lottery Choice Models

Having estimated the parameters of the first stage, expected access probability model, the second stage, lottery choice model is estimated. Given the large number of lotteries from which to choose (136), choice sets are generated for each of the 18,708 applicants by random draws (e.g., Parsons and Kealy, 1992). Choice sets comprised of J = 5 to 20 alternatives are constructed (in 5-alternative increments), and McFadden's conditional logit model is estimated. Estimates from the access probability model are then used for the generation of individual-specific expected access probabilities for the alternatives. For additional comparison, we also estimate a naive, RUM that ignores the access probabilities (or assumes they are equal to one).

Overall, the models perform quite well as gauged by the significance of the parameter estimates and the goodness of fit measures (Table III). In all cases the fits of the expected utility models are nearly identical to that of the naive model (RUM) as gauged by the goodness-of-fit measures. With the RUM it is assumed that the access probability is one for all alternatives. Thus, Ln(Loss) and Probability are absent from the model. In all REUM cases, the expected loss is found to have a significant and large negative effect on the probability of choosing an alternative. The two differences in signs of the estimated coefficients between the REUM and RUM are attributable to the interaction form of the variables in the former.

V. Simulations and CS Estimation

In addition to analyzing lottery participation, the model may be used to estimate welfare changes resulting from amendments to the lottery system. Similarly to the choice analysis, the probability of being granted access must be accounted for, and in particular the changes in the access probabilities from the status quo policy setting that may result from changes in policy, the structure of the lottery system, or from factors external to the particular system of interest. Thus, in the estimation of benefits, predicted changes in the individual-specific probabilities of being drawn are necessary. The heteroscedastic probit model is used to obtain expected access probabilities subsequent to changes in the lottery system (Table II).

We estimate welfare changes at three levels. First, when the probability of access is altered due to some external event that reduces the number of participants (represented by expression 2). For example, the imposition of a quota on the proportion of licenses to award a particular group in one state (e.g., nonresidents) may lead to changes in participation and access probabilities in the lottery system of interest. Given the empirical specification, the access probability and indirect utility are altered. The scenario considered is a twenty-five percent reduction in the number of lottery participants.

Second, welfare changes are estimated when the access probability and indirect utility are altered from an internal (system-specific) event (represented by expression 3). For example, changes in the numbers of licenses are common across state lottery systems as successful herd restoration or propagation efforts often lead wildlife biologists to increase the numbers of licenses to distribute. These numbers determine, in part, the access probabilities while also serving as attributes of the lottery-rationed alternatives. The compensating surplus is estimated for a twenty-five percent increase in the number of awarded licenses. We assume that a change in the number of licenses is not met with a change in the number of participants.

Finally, welfare changes are estimated for the situation where a change in a quality attribute affects indirect 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 are the adopted access probability measures and the inclusion of expected losses. Twenty-five percent increases in the harvest rate and the cost of access are considered.

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

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

The terms $E(L_j)^0$ and $E(L_j)^1$ denote the estimated expected utilities before and after the change, respectively. The absolute value of β_{TC} is an estimate of the marginal utility of income. A natural question arises regarding the extent of the deviation between REUM- and RUM-generated surplus estimates. Thus, for additional comparison, we present surplus estimates obtained from the naive model.

Results from the REUMs and RUMs indicate that surplus estimates are robust to the number of alternatives contained in the choice set (Table IV), at least over the range evaluated here. While others have found welfare estimates to be sensitive to the size of the choice set, only a few hundred individuals were analyzed rather than the thousands used here (see e.g., Parsons and Kealy, 1992).

Consider first the case where the number of participants is reduced by twenty-five percent. In this case, 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 increases in these probabilities cannot even be calculated. Whereas for the various REUMs, the compensating surplus for a twenty-five percent reduction in the number of participants is estimated to be about thirty dollars. In the second scenario the number of awarded licenses increases by twenty-five percent. The results from the REUMs 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 are generally determined by wildlife biologists, such a license increase might result from positive shocks to herd populations. Finally, in the third and fourth scenarios, quality changes are assumed to affect indirect utility but not the expected access probability. In both cases, the REUM generated surplus estimates are exceeded by the RUM estimates but only slightly so for the change in access cost.

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.

To summarize the results from this recreational lottery study, we find that the REUM versus RUM distinction has greater impact on estimated surplus values than varying the size of the choice set (for the range evaluated here).[9]

VI. Conclusions

Discrete choice models of individual behavior have emerged as the preferred approach for estimating the consumptive use values for changes in environmental quality. However, pressures on natural resource stocks and equity concerns have influenced the adoption of lotteries for rationing access opportunities and resource stocks. Considering this, and recognizing that lotteries randomly ration goods, 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 individual-specific, expected probability of being granted access. Observed outcomes (drawn or not drawn) are modeled in order to generate individual-specific expected access probabilities for the alternatives in the participants' choice sets. Welfare estimates are obtained from simulated policy changes affecting individually and jointly the access probability and indirect utility. Although estimated compensating surplus is robust to choice set size, failure to account for access probabilities is

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

found to lead to large differences in the welfare estimates.

As a concluding note, despite some recent contributions we argue that there is still a significant gap in the collective knowledge about recreation demand modeling and lottery participation. Given the prevalence of, and growth in, lotteries for rationing access opportunities and that contributions in this area are relatively limited, continued research efforts are clearly warranted.

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Table I. Variable Definitions and Summary Statistics

Variable	Definition	Mean	Standard Deviation
Age	Applicant age	40.85	13.66
Age Squared	Applicant age squared	1855.80	1185.09
Male	1 if applicant is male; 0 otherwise	0.91	0.29
Ln(Access Cost)	Natural logarithm of the $6 participation fee + license fee + $0.526*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
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
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 II. Estimates of Binary, Access Probability Models

N = 29,560	Probit	Heteroscedastic Probit	Logit	Skewed Logit
Age	0.016*** (0.003)	0.008*** (0.002)	0.025*** (0.005)	0.038*** (0.010)
Age Squared	-0.0002*** (0.00004)	-0.0001*** (0.00002)	-0.0003*** (0.00006)	-0.0005*** (0.0001)
Male	0.119*** (0.029)	0.050*** (0.018)	0.190*** (0.049)	0.296*** (0.089)
Subjective Probability	1.646*** (0.028)	0.978*** (0.031)	2.742*** (0.049)	5.586*** (0.648)
Constant	-0.964*** (0.068)	-0.527*** (0.044)	-1.574*** (0.113)	-0.838*** (0.207)
$Ln(\sigma^2)$				
Licenses	—	-0.003*** (0.0001)	—	—
Applicants	—	0.00001 (0.00007)	—	—
$Ln(\alpha)$	—	—	—	-1.127*** (0.143)
Log-Likelihood	-18,001	-17,689	-17,988	-17,960
Pseudo R^2	0.094	0.109	0.094	0.096

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

Table III. Conditional Logit Estimates of Lottery Choice Models

	REUM				RUM			
Variable	J = 5	J = 10	J = 15	J = 20	J = 5	J = 10	J = 15	J = 20
Ln(Access Cost)	-3.389***	-3.520***	-3.564***	-3.567***	-1.950***	-2.066***	-2.107***	-2.116***
	(0.044)	(0.039)	(0.037)	(0.036)	(0.025)	(0.022)	(0.021)	(0.021)
Ln(Loss)	-11.690***	-11.791***	-11.780***	-11.615***	----	----	----	----
	(0.404)	(0.355)	(0.342)	(0.334)				
Licenses	0.014***	0.014***	0.013***	0.013***	0.008***	0.007***	0.007***	0.007***
	(0.0002)	(0.0002)	(0.0002)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Probability	-6.886***	-6.699***	-6.556***	-6.313***	----	----	----	----
	(0.561)	(0.496)	(0.478)	(0.468)				
Harvest	0.494***	0.630***	0.673***	0.686***	0.610***	0.697***	0.728***	0.738***
	(0.089)	(0.080)	(0.077)	(0.075)	(0.047)	(0.042)	(0.041)	(0.040)
NE	0.030	0.062	0.086*	0.066	-0.135***	-0.112***	-0.095***	-0.097***
	(0.057)	(0.052)	(0.051)	(0.050)	(0.033)	(0.030)	(0.029)	(0.029)
SW	1.600***	1.772***	1.819***	1.860***	0.824***	0.934***	0.966***	1.004***
	(0.053)	(0.048)	(0.046)	(0.046)	(0.029)	(0.026)	(0.025)	(0.025)
SE	1.618***	1.883***	2.023***	2.096***	0.939***	1.112***	1.198***	1.246***
	(0.105)	(0.090)	(0.085)	(0.082)	(0.051)	(0.043)	(0.041)	(0.040)
Quality	-0.100	-0.280***	-0.407***	-0.460***	0.180***	0.144***	0.101***	0.085***
	(0.089)	(0.083)	(0.080)	(0.079)	(0.036)	(0.033)	(0.032)	(0.031)
Bull	0.771***	0.772***	0.742***	0.772***	0.718***	0.756***	0.737***	0.759***
	(0.073)	(0.065)	(0.063)	(0.061)	(0.045)	(0.040)	(0.038)	(0.038)
Antlerless	0.612***	0.526***	0.507***	0.508***	0.618***	0.595***	0.573***	0.571***
	(0.078)	(0.070)	(0.067)	(0.066)	(0.046)	(0.041)	(0.039)	(0.038)
Opening	0.189**	0.294***	0.318***	0.402***	0.077*	0.144***	0.168***	0.217***
	(0.089)	(0.079)	(0.075)	(0.074)	(0.045)	(0.039)	(0.037)	(0.036)
Holiday	-0.250*	-0.281**	-0.326***	-0.304***	-0.252***	-0.269***	-0.294***	-0.286***
	(0.128)	(0.115)	(0.110)	(0.108)	(0.068)	(0.060)	(0.057)	(0.056)
Late	3.445***	3.558***	3.595***	3.588***	1.517***	1.562***	1.592***	1.599***
	(0.103)	(0.091)	(0.088)	(0.086)	(0.066)	(0.057)	(0.055)	(0.054)
N	93,540	187,080	280,620	374,160	93,540	187,080	280,620	374,160
Ln(likelihood)	-19,834	-30,585	-37,315	-42,325	-19,733	-30,328	-36,977	-41,926
Pseudo R^2	0.341	0.290	0.264	0.245	0.345	0.296	0.270	0.252

Notes: ***, **, and ** denote significance at the 1%, 5%, and 10% level, respectively.

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

N = 18,708	REUM				RUM			
	J = 5	J = 10	J = 15	J = 20	J = 5	J = 10	J = 15	J = 20
Scenario:								
25% Reduction in Applicants	$36.96 (30.00)	$32.77 (25.60)	$30.90 (23.18)	$29.22 (21.00)	----	----	----	----
25% Increase in Licenses	149.73 (88.56)	141.05 (75.97)	137.60 (69.21)	134.44 (63.35)	$54.80 (25.49)	$51.47 (20.75)	$50.07 (18.44)	$49.25 (17.18)
25% Increase in Harvest Rate	5.70 (3.86)	7.23 (3.71)	7.69 (3.34)	7.90 (3.07)	12.98 (8.53)	14.60 (7.22)	15.14 (6.34)	15.39 (5.76)
25% Increase in Access Cost	63.26 (20.90)	63.76 (19.37)	63.91 (18.79)	63.95 (18.67)	66.38 (18.77)	68.28 (18.24)	68.98 (18.20)	69.21 (18.10)

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