ESTIMATING THE VALUE OF HUNTING LICENSE: 
A CASE STUDY OF COLORADO ELK PERMITS

by

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ABSTRACT

The purpose of this thesis was to develop a method of assessing the marginal value of limited elk hunting licenses in Colorado. The measure of marginal value constructed used hunters’ opportunity costs of securing these licenses, and it does not rely on travel costs or surveys. The statistical inquiry used both ordinary least squares and the ordered probit procedure to measure hunters’ marginal willingness-to-pay for various hunting characteristics. The results imply that higher demand for licenses is closely linked to unmeasured quality variables and that efficiency and revenue to the Colorado Division of Wildlife could be increased by reallocating hunting licenses from marginally lower valued characteristics to marginally higher ones if reallocation is not costly.
CHAPTER 1

INTRODUCTION

In the Western United States state wildlife agencies control most attributes of big game wildlife management. This management includes setting seasons, bag limits, and license fees. Regulations are used to balance hunting opportunities with species populations, and fees are used to ration licenses and generate revenues. To the economist this balancing and rationing requires knowing the value of various attributes of big game hunting, but these values are difficult to ascertain in the absence of a market.

The thesis attempts to quantify the values of different elk hunting attributes. It uses data on the limited number elk licenses in Colorado and the financial opportunity cost of the non-price margins of competition. These opportunity costs include fees to enter the lottery and earning points for each year the applicant is not drawn. The resulting values provide information to resource managers about what herd and hunt characteristics are marginally worth to hunters.

To understand the importance of knowing the values of hunting attributes, consider the following willingness-to-pay tradeoffs. Suppose there is an area where one hunter would be willing to pay $5000.00 to hunt if he has a 90 percent chance of harvesting a trophy bull, and there are 50 hunters who would pay $20.00 to hunt if each had a 10 percent chance of harvesting a trophy bull. The value maximizing regulation
would entail managing the elk in the area to assure the one hunter the right to hunt there with a 90 percent chance of harvesting a trophy bull. However, political pressure makes management based solely on maximizing willingness-to-pay from hunters unlikely. Agencies are under political pressure to accommodate more hunters. Hence hunting regulations that permit unlimited license bull hunts are often the norm. In order to continue to offer licenses in this manner, agencies are driven to manage elk herds for maximum sustainable yield rather than maximum value (Anderson and Hill 1995, 91).

The down side of regulations that permit unlimited license bull hunts is high congestion, low probability of success, and very few mature bulls.

As congestion problems increase, agencies are forced to consider non-price rationing schemes designed to reduce the quantity demanded. Such non-price rationing schemes include shorter seasons, antler requirements, sex specification, and primitive weapon requirements such as archery or muzzleloader only seasons. The hunts associated with each of these restrictions provide different benefits and costs to hunters. For example, the potential benefits particular to archery hunts in Colorado are low congestion conditions, high number of hunting days, and a higher probability of seeing mature bulls because hunting is during the rut. On the cost side, the archery hunter must get close to the animal in order to make a kill and must give up other opportunities to hunt with a rifle. The major benefit to the rifle hunter is that he does not need to be as close to an animal to have a shot opportunity, but he will encounter high congestion, fewer days of hunting, and no hunting during the rut. Hence, each hunter must decide which type of hunt maximizes his utility.
These individual decisions provide a way of inferring what hunt attributes are marginally worth, and whether the agency can increase the value of hunting by offering more or fewer of the attributes. If it were possible for managers to choose between extending the rifle season for a day or increasing hunter success by 10 percent in future years, at the margin, which would be worth more to hunters? If there is an area in which the Colorado Division of Wildlife issues 50 archery, 100 muzzleloader, and 200 rifle licenses to be sold, and demand at the official price is greater than the supply in each case, would reallocation of licenses increase the overall value to hunter? Using data from limited license lotteries can help answer these and similar questions.

Western states including Colorado rely on lotteries to allocate limited elk licenses in instances where, even with the user restriction regulations in place, demand at the official price is greater than the available supply. These lottery systems require hunters to submit an application and usually require a non-refundable application fee. Licenses issued often contain restrictions on the types of weapons a hunter may use, on the time period in which hunting is allowed, on the sex of the animal that can be killed, and on antler requirements.

Economic principles suggest that even with lotteries in place, an excess willingness-to-pay for limited elk licenses will force the market to clear along some other margin. The Colorado quasi-lottery system provides an excellent example of how this competition might take place. Every time a lottery applicant is unsuccessful in drawing his first choice, he is given a preference point that entitles him to preferential treatment in
subsequent lotteries.\textsuperscript{1} Competition between hunters for licenses takes place through the use of these preference points.

The thesis will proceed as follows. Chapter 2 will review the techniques that have been used by economists to estimate the value of hunting. The remainder of the thesis will then use data from Colorado limited elk license lottery to achieve two objectives. First, those data will provide a way of valuing the limited elk licenses in Colorado by calculating the financial opportunity cost of the appropriate non-price margin of competition. The valuation method presented should be useful as a guide for the differential pricing of different types of limited elk licenses. Second, the data will reveal marginal preferences of hunters through the relative values of differing limited licenses. The data will provide information about what attributes of the hunting experience are marginally more valuable to hunters. These values will allow us to answer questions about whether managers can increase the value of hunting by changing the current allocation of limited elk licenses among the different types of elk hunts.

\textsuperscript{1} Although it will be discussed later in the thesis, the specifics on how the limited elk license disbursement system in Colorado is given in Colorado Hunting Season Information (1996).
CHAPTER 2

LITERATURE REVIEW

For the last two decades outdoor recreation economists have focused on methods of measuring benefits associated with a non-market good (Nickerson 1990, 437). Through various methods they have attempted to find willingness-to-pay measures for goods for which people do not explicitly pay such as air quality, outdoor recreation, and wildlife. These approaches are criticized by some and praised by others (Batie and Shabman 1979, 931). The methods for measuring benefits generally fall into one of three categories: contingent valuation, travel cost, and hedonic pricing. We will briefly review the three methods and critique their usefulness for policy analysis.

Contingent Valuation

The contingent valuation method uses surveys to elicit willingness-to-pay for a non-market good. In general the method proceeds as follows. A sample of the population is asked questions about its valuations of some good through phone, mail, or personal surveys. These surveys often phrase valuation questions as some type of bidding game, and they usually specify a payment vehicle that describes how the costs of providing the good in question will be paid. The responses of the sample are then used to estimate an average willingness-to-pay for the good. Finally, the estimated
willingness-to-pay measures are used to extrapolate the total value of the good to the entire population.  

Contingent valuation has been used to estimate the value of hunting many big-game species. Sorg and Nelson used the iterative bidding contingent valuation technique to find willingness-to-pay measures for Idaho elk hunting in 1983. They found that average net willingness-to-pay (net of current required expenditures such as license fees and travel expenditures) per trip was $92.54, and net willingness-to-pay per day was $22.57.  Using data acquired in the 1985 National Survey of Fishing, Hunting, and Wildlife, Michael Hay (1988) of the U.S. Fish and Wildlife Service found that the net economic value (net of reported trip expenditures) per day of elk hunting in Colorado was $40.00.

There are many potential difficulties with use of the contingent method. To discuss all these problems is beyond the scope of the thesis. However, some of the most significant problems for wildlife policy are the following. First, when people say that they will spend a certain amount for the right to hunt they may not be accurately stating their true willingness-to-pay. Boardman et al. (1996, 352-365) points out that survey information is subjected to numerous biases including sample bias, non-response bias, interviewer bias, non-commitment bias, and starting point bias. It is true that questioning techniques have been refined over the years, but most assuredly they are not perfect.

2 For a more complete discussion of the contingent valuation method and possible problems associated with its use see Boardman et al. (1996, 345-369).

3 Sorg and Nelson, (1986).
Second, the numbers generated through this method are infra-marginal average numbers. That is, they are values that the average consumer is willing to pay, not the marginal consumer. Even if survey information is reliable, the usefulness of these infra-marginal average willingness-to-pay numbers in policy decisions is limited. As Nickerson points out “the usefulness of this work seems largely confined to two types of situations: one where recreational valuation can help policy makers choose among alternative projects and the other in the context of evaluating completed projects” (1990, 437).

Marginal effects of decisions are more useful information to public managers who often make decisions about incremental changes. For example, what would be the effects if a manager decided to slightly reduce fish stocking on a given river? It is doubtful that prior knowledge of average value would be instructive in informing the manager of the possible welfare loss due to decreased fishing opportunities. Marginal values, coupled with information from a biologist regarding the effect of this change on fish population, would prove very useful to understanding this welfare change.

**Travel Cost Method**

The regional or zonal travel cost method infers willingness-to-pay based on the different travel expenditures to a given site. As distance to a hunting site and time costs of travel increase, per capita participation will decrease. By using differences in travel costs incurred by hunters as proxies for different prices for participation, economists generate a demand curve for the good in question. For example, a researcher doing a travel cost study for moose hunting in Alaska would be interested in the costs incurred by
individuals who participate in a hunt. Such costs may include the opportunity cost of time, the opportunity cost of the vehicle used, the cost of lodging, fuel, and food, and the price of the hunting license. These costs obviously differ among people, households, and areas. An assumption is usually made about the opportunity cost of time in order to facilitate an analysis that is based not on the individuals or households but on the differing areas that are present in the sample.

The data collected or generated through these assumptions are then used to estimate the number of trips that are taken by a representative individual as a function of the total cost incurred, quality of the hunting site, substitute sites available, and other relevant socioeconomic variables. The resulting per capita demand curve can be aggregated to create a market demand curve for the site. Analysts then use this market demand curve to calculate total willingness-to-pay for hunting at the particular location. 4

Average willingness-to-pay values for hunting that come from the use of the travel cost method are typically high when compared to the license fees that wildlife agencies charge. Using the travel cost method to find willingness-to-pay for deer hunting in Alaska, Swanson, Thomas, and Donnelly (1986) found that the average resident deer hunter valued the experience at $861.00. Non-residents valued the experience at $1406.00. The average value for a deer-hunting trip for residents and non-residents was $394.00 and $1350.00 respectively. Net of expenditures the average value per trip for residents was $155.00 and for non-residents was $101.00. Sorg and Nelson (1986) used a

4 For more information on the regional travel cost method see Boardman et al. (1996, 324-330).
similar method and found the average willingness-to-pay per trip for elk hunting in Idaho was $176.29, which resulted in a net value of $99.82.

As with the contingent method, the travel cost method has many potential problems. First, the same criticism of yielding infra-marginal average rather than marginal value also applies. Second, the use of travel cost method generally estimates the willingness-to-pay for an entire site rather than specific features of a site. Values for specific features are often the necessary information that is lacking for policy analysis. Third, the method relies on subjective decisions of what is the appropriate opportunity cost of travel time. Fourth, the trip itself may have value, and if so, the value of a single activity can only be discerned when a subjective decision is made about the value of additional purposes of the trip.  

Hedonic Method

In attempting to provide information that is more instructive to wildlife resource managers, some researchers have used the hedonic pricing method. This method infers the value of a single attribute of a good from the total market value of the good. In the case of hunting the hedonic method utilizes the differing prices for hunting leases with different characteristics to place a value on certain attributes of hunting. The hedonic pricing method is used to place a value on an attribute of a good that is not traded separately from the entire good, but is capitalized into the price of the entire good that is

5 Many of the problems with travel cost method which are presented here are paraphrased from Boardman et al. (1996, 329-331).
traded on the market. For example, the number of deer present on a leased tract of land is not traded explicitly, but the number of deer present will almost certainly affect lease price. Or to take a non-wildlife example, scenery from a house is not traded on the market explicitly, but the quality of scenery will affect the value of a house.6

The first stage in any hedonic price study is the specification of a hedonic price function and its empirical estimation. The proper specification involves relating the price of a traded good to all of those attributes that theoretically affect its value. For example, a hedonic price function for deer hunting leases might relate the price of a lease to accessibility, number of deer harvested, number of acres in the lease, congestion, lease length, availability of free hunting areas which serve as possible substitutes, number of mature buck deer harvested, scenery, likelihood of seeing game, and weather variables. Examples of wildlife markets include whitetail deer hunting in Texas, Canadian geese hunting in Maryland, and waterfowl hunting in Minnesota (Livengood 1983).

By using the hedonic approach on deer hunting leases in Texas, Livengood (1983) was able to estimate a demand curve for harvested deer and provide additional information about the effect certain variables have on hunting lease prices. He found that individuals were willing to pay about $25.00 to be assured of harvesting one deer and about $13.00 to harvest an additional deer. Perhaps more interesting than the demand curve for deer are the estimates obtained for the effect of other variables on lease price. He found that the number of hunters (used as a proxy for congestion) had a significantly

6 For a more complete discussion of the hedonic price method see Boardman et al. (1996, 318-324)
negative effect on lease price. He also found that the number of deer killed per season, the number of acres in the lease, the length of the lease, the availability of free hunting sites to hunters, and the distance to the lease site all had a significantly positive effects on lease price.

The hedonic method is not subjected to as many conceptual problems as the other two methods. As well, one could make an argument that the values generated through its use are more useful in policy analysis because they are marginal values. The primary problem with using hedonic studies to value big game hunting is that they require an established market for an asset that incorporates the value of big game. Because there are a few isolated markets for private elk hunting in Western states, they only provide limited information about public hunting in general.

In summary the primary problem with previous studies with regards to elk hunting values is that they either result in value measures that are not very useful to resource managers who control elk hunting or they can not be applied to the situation at all. Because hedonic method usually can not be applied to elk hunting, travel cost and contingent valuation have been the primary source of values for elk hunting. However, as pointed out, both the travel cost and the contingent valuation usually yield average values that are of limited use.
An alternative approach to obtaining a value for elk hunting is to develop and use a model that explains participation in lottery distribution mechanisms. The characteristics of lottery systems vary by state. In Washington and Montana, for example, elk licenses are distributed in a purely random matter. In other states such as Utah, Oregon and Colorado the lottery systems are not random. One can change his odds of receiving a limited license by being unsuccessful in the drawing in years past.

Random Lottery Analysis

Peter Nickerson’s study of “The Demand for Regulation of Recreation: The Case of Deer and Elk Hunting in Washington State” (1990) used publicly available lottery data in an innovative way to show the effects on consumer demand of certain hunting regulations and hunting characteristics. He developed a theoretical model that explained the individual’s decision about participation in a random lottery. His model framework is as follows. Let \( V_j (Y, P, H, q_j) \) be the amount of money an individual would be willing to pay for permit \( j \) if it were available with certainty. \( V_j \) is a function of \( Y \)-income, \( P \)-prices, \( H \)-household characteristics, and \( q_j \), which are characteristics of the \( j^{th} \) permit. Let \( S_j \) be the number of permits available for the \( j^{th} \) lottery. Let \( N_j \) be the total number of applicants
in the \( j \)th permit lottery. Then \( S_j/N_j \) is the probability of winning permit \( j \). Lastly, let \( P_L \) be the non-refundable price of entering the lottery. Then the expected value of entering and winning the permit is \( (S_j/N_j)(V_j - P_L) \). The expected value of entering and not being drawn is \(- (1 - (S_j/N_j))(P_L)\). So, the expected value of entering the \( j \)th license lottery, \( E(L_j) \), is given by the sum of its expected outcomes or
\[
E(L_j) = (S_j/N_j)(V_j) - P_L
\]
A risk neutral utility maximizer will enter the lottery as long as the sum of the expected value of its outcomes is greater than 0 or
\[
E(L_j) = (S_j/N_j)(V_j) - P_L \geq 0
\]
Because the rules allow participation in only one drawing, an individual will participate in the drawing that gives him the highest expected value. Nickerson described the individuals decision as a set of binary indices, \( d_1, \ldots, d_n \), where \( d_j \) equals 1 if the \( j \)th drawing is chosen and 0 if not chosen. The choice of lottery participation for the wealth-maximizing individual is given by
\[
d_j = 1 \quad \text{iff} \quad (S_j/N_j)(V_j) - P_L \geq 0 \quad \text{and} \quad (S_i/N_i)(V_i) \geq (S_j/N_j)(V_j)
\]
\[
d_j = 0 \quad \text{otherwise} \quad \text{where} \quad j = n, \ i = 1 \quad \text{to} \quad n, \ j \neq i.
\]
The \( d_j \)'s give the individual demand curves for licenses, given each consumer can purchase only one license. The sum of these individual demand curves gives the aggregate demand for each type of license. This relationship allowed Nickerson to use changes in the number of applications for differing types of licenses to make inferences on how certain regulations and hunt characteristics affect demand for limited licenses.
After specifying the empirical equivalents to the theoretical variables, Nickerson estimates how hunt attributes affect the demand and expected values of limited licenses. For example, as hypothesized, restrictions on hunting such as those allowing only muzzleloaders, trophy bulls, and antlerless animals negatively affect the demand for licenses. However, Nickerson found that a restriction allowing only antlerless animals did not have much effect on license demand. Nickerson used this realization to assert that many hunters are not involved in the decision making process of resource managers. According to Nickerson, hunting club input is the dominant factor in the policy decisions which are made, and these hunting clubs often lobby against antlerless only hunts and for trophy hunts. This point was used to validate the usefulness of lottery data analyses. The most surprising finding by Nickerson was that hunters’ success percentage in harvesting an animal was not significant. As he explains, his use of dummy variables for each area that were intended to capture all of the characteristics for which he could not control may have captured the effect of hunter success on consumer demand.

By using Nickerson’s model in a different way, it is possible to get a marginal value for different hunts in areas where markets for big game do not exist and where a random lottery is used as the mechanism for permit distribution. From the discussion above we know that an individual will enter the $j^{th}$ license lottery as long as the sum of the expected value of its outcomes is greater than 0 or

$$E(L_j) = (S_j/N_j)(V_j) - P_L \geq 0.$$ 

Further, we know that the marginal lottery participant will be just indifferent about entering. For the marginal person the $E(L_j) = 0$. Solving $E(L_j)$ for $V_j$ we find that
Thus, the marginal lottery participant in the $j$th license lottery is willing to pay $(N_j/S_j)P_L$ in order to acquire the license with certainty. Using this relationship and data from states that use a random lottery, would allow us to infer marginal values from expected values.

The problem with this approach, however, is that most Western states no longer use a truly random lottery to distribute limited elk licenses; weighted lotteries based on the lack of success in previous lotteries are common. The system used in Colorado is an example of where preference points earned in unsuccessful drawings allow the participant to "buy" a given license.

Marginal Value From The Colorado System

The Colorado system allows an alternative to Nickerson’s expected value approach because hunters have opportunity costs in obtaining licenses. As Barzel (1997) has noted, when a good is forcibly priced below the market clearing level, demanders will compete on non-price margins until the market clears. This "rationing by waiting" will drive the market to clear along some non-price margin. Suppliers of the good may also compete by reducing the quality of the good. For example, when the price of gasoline was regulated in the early 1970s, octane levels typically fell and services associated with the purchase of gasoline declined (Barzel 1997, 27-28). In the case of wildlife, agencies

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7 The notation used here was borrowed from Nickerson (1990).
can reduce the quality of hunting by such means as shortening seasons and closing roads (Anderson and Hill 1995, 95).

If there is still excess demand after quality adjustment, demanders will compete for the good in other ways. Individuals may participate in violence or spend time waiting in line. “The specific nature of the restrictions delineates the margins of competition” (Barzel 1997, 17). Whatever criteria is required to acquire the good, one thing is clear: the marginal individual must be at a point where the total cost of acquiring the good must be equal to his total valuation of it. Otherwise rents would remain, and more competition would occur.

The Colorado Quasi-Lottery System

Colorado’s lottery system provides a unique type of competition among demanders for limited elk licenses. In Colorado the selection system for a limited elk license is quite different from a random drawing. An applicant for a limited license has two choices, a first choice and a second choice. For these choices he must select one of the 170 game management-hunting units and must decide what type of hunt he desires. The categories describing these options are listed in Table 1. After an applicant selects the two desired choices, he must send in the entire price of the permit plus a $3.00 non-refundable processing fee. The agency keeps the permit price for about two or three months depending on the year in question. If an applicant is unsuccessful with his first choice, his permit price is refunded, but his $3.00 application fee is kept. He is, however, awarded a preference point that can be applied to a future elk license drawing. If he is
unsuccessful again, he receives another preference point, and the preference points can be accumulated.

Preference points (PP) give the applicant preference in the drawing mechanism for elk hunting privileges in Colorado. For each limited license hunt, the computer starts with those applications with the highest number of PP and works its way down. The computer automatically awards the licenses to applicants with the highest number of PP and works its way down until it reaches the point where the number of applications with the same number of PP equals or exceeds the number of available licenses.  

Table 1: Limited Elk License Options

<table>
<thead>
<tr>
<th>TYPE OF HUNT</th>
<th>DEFINITION</th>
<th>PERMISSIBLE HUNTING DATES (1996)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Either Sex Archery</td>
<td>Hunt that allows for either sex to be harvested with archery weapons only</td>
<td>Aug. 31-Sept. 29</td>
</tr>
<tr>
<td>Bull Muzzleloader</td>
<td>Hunt that allows for only bull elk to be harvested with muzzleloader weapons only</td>
<td>Sept. 14-Sept. 22</td>
</tr>
<tr>
<td>Cow Muzzleloader</td>
<td>Hunt that allows for only cow elk to be harvested with muzzleloader weapons only</td>
<td>Sept. 14-Sept. 22</td>
</tr>
<tr>
<td>Bull Early Rifle</td>
<td>Prior to regular season hunt that allows for only bull elk to be harvested by any legal method</td>
<td>Oct. 1-11</td>
</tr>
<tr>
<td>Cow Early Rifle</td>
<td>Prior to regular season hunt that allows for only cow elk to be harvested by any legal method</td>
<td>Oct. 1-11</td>
</tr>
<tr>
<td>Bull Regular Rifle</td>
<td>Regular season hunt that allows for only bull elk to be harvested by any legal method</td>
<td>Three Separate Seasons: First, Oct. 12-16 Second, Oct. 19-30 Third, Nov. 2-10</td>
</tr>
</tbody>
</table>

The computer does not distinguish between in-state and out-of-state hunters.
<table>
<thead>
<tr>
<th>TYPE OF HUNT</th>
<th>DEFINITION</th>
<th>PERMISSIBLE HUNTING DATES (1996)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cow Regular Rifle</td>
<td>Regular season hunt that allows for only cow elk to be harvested by any legal method</td>
<td>Three Separate Seasons: First, Oct. 12-16 Second, Oct. 19-30 Third, Nov. 2-10</td>
</tr>
<tr>
<td>Bull Late Rifle</td>
<td>Post regular season hunt that allows for only bull elk to be harvested by any legal method</td>
<td>Dates vary by unit</td>
</tr>
<tr>
<td>Cow Late Rifle</td>
<td>Post regular season hunt that allows for only cow elk to be harvested by any legal method</td>
<td>Dates vary by unit</td>
</tr>
<tr>
<td>Bull Wildlife Ranch</td>
<td>Hunt on a government contracted wildlife ranching area that allows for only bull elk to be harvested by any legal method</td>
<td>Dates vary by ranch</td>
</tr>
<tr>
<td>Cow Wildlife Ranch</td>
<td>Hunt on a government contracted wildlife ranching area that allows for only cow elk to be harvested by any legal method</td>
<td>Dates vary by ranch</td>
</tr>
</tbody>
</table>

At that point the remaining licenses are distributed randomly among the applicants at that preference point level. For example, assume John has five PP and his first choice is for an archery only tag in Game Management Unit (GMU) 10 in year $t$. If there are twenty tags available in GMU 10 for year $t$ and no one else who applies has five PP, John will automatically receive the license. He will receive the license with certainty as long as the total number of applicants with five or more points is less than twenty. However, if fifteen people have more than five PP and ten people have five, then he is not assured a license. The fifteen people with more than five preference points will be guaranteed a license, and John will be put into a random lottery with nine other people. Hence, his
probability of receiving a license is 0.50. Combining this distributional mechanism with some key assumptions gives the model for the thesis.\(^9\)

**Model Of License Cost In Colorado**

In the case of limited license elk hunting in Colorado an obvious margin for competition is participation in repeated lotteries to accumulate preference points. Assuming that hunters know how many preference points are required in order to obtain a given permit with certainty\(^{10}\) and assuming that applicants receive little value from their second choices,\(^{11}\) the opportunity cost of acquiring and holding these points plus the outright price will in effect drive the price of a hunting license to the market clearing price. This process can best be described with the help of Figure 1. Assuming that supply for a particular license \(j\), \(S_j\) in Figure 1, is based on population objectives, the availability of habitat and is not responsive to price, the market clearing price for license \(j\)

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\(^9\) The proceeding discussion about how the drawing mechanism works in Colorado can be found in Colorado Hunting Season Information (1996).

\(^{10}\) In Colorado the Colorado Division of Wildlife publishes a booklet entitled Big Game Hunting Statistics each year. Among other things, the booklet contains information concerning how many preference points were needed in the previous year to acquire any limited license. These booklets are available in sporting goods stores, department stores, grocery stores, through the Colorado Outdoors magazine, and by request from the CDW. Given the availability of this information and the fact that preference point requirements within any given hunt do not change much from year to year, this assumption is reasonable.

\(^{11}\) According to Henrietta Turner of the CDW, in 1997 less than half of all limited license elk hunt applicants even bothered to list a second choice: 60,550 out of 144,825. Of those who did apply with a second choice, only about 10 percent or 7,045 were successful in drawing a permit. The fact that less than 5 percent of total applicants are successful suggests that hunters do not get much value from their second choice. If hunters do value their second choice, the estimate of marginal willingness-to-pay will be too high.
would be $P_0$. Because $P_0$ is above the license price of $33.25$, which is administratively required to purchase the license, excess demand exists. The requirement of PP to obtain the license will push the price towards the market-clearing price of $P_0$.$^{12}$

*Figure 1: Excess Demand for a Given License*

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$^{12}$ If there is a situation where $P_0$ is below $33.25$ there is no information contained in the lottery data that indicates what the marginal willingness-to-pay would be in the absence of the lottery. One can only say that the price would be less than $33.25$. 
Through competition for the license, preference points will continue to rise until the marginal consumer receives no surplus. If there is excess demand at the going price including PP, the marginal applicant will enjoy some consumer surplus implying he would be willing to pay more. Therefore, the opportunity cost of acquiring and holding PP plus the outright price should equal the amount that the marginal applicant is willing to pay for the permit. Acquiring and holding preference points is not free; it requires a financial commitment resulting from the present value of non-refundable license fees and refundable license fees held by the state for approximately two months.

The financial commitment for obtaining a given elk license $j$ can be specified as follows. First, the cost of acquiring a preference point in any year is given by:

$C_i = (LP)(f)(r) + 3.00$

where $LP$ is the license fee that must be submitted, $f$ is the fraction of the year for which the license fee is retained by the state before being refunded if the applicant is not drawn, $i$ is a yearly index, $r$ is the discount rate, and $3.00$ is the non-refundable application fee.

For Colorado residents $LP = \$30.25$, and for non-residents, $LP = \$250.25$ for years 1990-1996. Prior to 1990 $LP = \$25.25$ for residents and $\$210.25$ for non-residents. In 1996 $LP$ was kept by the state for two months and in previous years it was kept for about 3.5 months. Therefore the total cost over time of a guaranteed license for a $j$ type hunt is

$TC_j = \sum_{i=0}^{t} C_i(1 + r)^i + LP$

where $t$ is the total number of years required to accumulate PP at one per year, $i = 0$ for the year in which the license is obtained back to year $t$, and $LP$ is the outright price paid
for the license.\textsuperscript{13} For example, if permit $j$ requires 5 PP in 1995 and $r = .08$ the total cost of a guaranteed license $j$ for a resident was $51.99, and for a non-resident is $302.11.

Clearly the total purchasing cost is not equal to the outright price.

There are many considerations that must be taken into account when evaluating the marginal values that are generated through Equation 2.\textsuperscript{14}

(1) Because the preference point system was started for elk hunts in 1984,\textsuperscript{15} the upper bound on PP to guarantee a license was thirteen in 1996, twelve in 1995 and so on.

(2) Since Equation 2 focuses on the marginal consumer that receives the license with certainty, there are situations in which using the lottery data will not reveal what the actual marginal value would be if licenses went to the highest bidder. Because we are dealing with a marginal value that arises for certain acquisition, we really can not say anything about what marginal willingness-to-pay is for individuals just below the certain acquisition level. This situation effects our estimates of marginal value in two instances. First, the amount required for certain acquisition of the license, as revealed in Equation 2, does not consider that there are individuals willing to pay just below this level who have a random chance at receiving the license. This lack of information about willingness-to-pay of demanders with uncertain acquisition may

\textsuperscript{13} For the 1996 estimates $i=0$ for 1996, for 1995 $i=0$ in 1995, and so on.

\textsuperscript{14} Equation (2) implicitly asserts that there is no cost to applicants of choosing a hunt and that foreknowledge of one's activities at a future point in time is costless. In other words information is perfect. If neither of these activities is truly costless then estimates given by Equation (2) will be biased downwards.

imply that the values generated through Equation 2 could over-state the actual
marginal values that would exist if licenses were sold outright. This can be seen with
the aid of Figure 2, where the total price paid to acquire license \( j \) with certainty is the
cost associated with five PP. The quantity distributed at this price is \( 0Q_L \). The
licenses remaining here, \( Q_L, Q_S \), are distributed randomly among all of those
participants who have paid the amount associated with 4 PP. If the discontinuous
threshold demand curve that appears through the preference point system reflects a
latent, continuous linear demand curve, the value that we get through the use of
Equation 2 will over-state the marginal value of license \( j \) that would appear if the
supply of licenses \( j \) were sold outright. Viewed another way the marginal
willingness-to-pay for certain acquisition of permit \( j \) is the actual margin that would
be paid if supply were equal to \( Q_s \). Everyone not willing to pay the price associated
with the preference point level required to receive the license with certainty would not
have a chance to receive it.

Second, we have no information about the marginal value for licenses which
require 0 PP to purchase with certainty. If a license requires 0 PP to obtain with
certainty, the demand for the license at a price of $33.25 is less than the available
supply. In this situation we have no information about how much lower the price
would have to be to sell all of the available licenses. We only know that the price
would have to be less than $33.25. For this reason, all licenses in which the available
supply is greater than demand are avoided in all estimations.
Figure 2: Marginal Willingness-to-Pay for Certain Acquisition
(3) The discount rate will affect the calculated value. For this reason estimations will allow \( r \) to vary from .06, .08, .10, and .12 in the calculation of marginal willingness-to-pay.

(4) The differential for in-state and out-of-state hunters in the context of the preference point system makes it more difficult to interpret the marginal value for licenses and increases the misallocation of permits. In Colorado, out-of-state hunters are required to pay at least $253.25, while in-state hunters are required to pay only $33.25. Given that these two prices still leave excess demand, competition ensues through preference point bidding.

To understand the distortion that results, consider Figure 3. For simplicity, assume that in-state and out-of-state hunters have identical demand curves, that the demand curves are continuous, that demand from in-state hunters and out-of-state hunters remains the same from year to year, and that only those bidding the required PP have a chance at receiving the license. Panel (a) represents the demand for license \( j \) by out-of-state hunters, panel (b) represents the demand by in-state hunters, and panel (c) shows the aggregate demand. If out-of-state and in-state hunters were required to pay the same market determined price for license \( j \), and no price discrimination or preference point system existed, the appropriate market demand curve would be \( D_0 \), the equilibrium price would be price \( P_\text{w} \), and license \( j \) would go to the highest valued users. However, given current policy a kink occurs in the aggregate demand at the bureaucratically set out-of-state price because out-of-state hunters who value the license at less than $253.25 are priced out of the market, so the
Figure 3: Marginal Willingness-to-Pay Under the Colorado System

(a) Out-of-State Demand, License \( j \)

(b) In-State Demand, License \( j \)

(c) Out-of-State Demand, License \( j \)
actual demand curve is \( D_1 \). The portion of the demand curve \( D_1 \) below the kink includes only in-state hunters willing to pay more than $33.25 and therefore terminates at $33.25.

Assume that there is a limited supply of permits shown by \( S_j \). If permits were allocated by a market determined price under the current policy that out-of-state hunters must pay at least $253.25, the market clearing price would be \( P_0 \), and every out-of-state hunter willing to pay $253.25 would receive the permit. Misallocation of the licenses would occur because many of the licenses received by in-state hunters could have gone to out-of-state hunters who valued them more.

When the basic price discrimination situation pointed out above is combined with the preference point system, further misallocation of licenses will occur. At the minimum prices of $253.25 for out-of-state hunters and $33.25 for in-state hunters, the excess demand shown in Figure 3 will put upward pressure on \( P_P \). As \( P_P \) rise, both out-of-state and in-state hunters will have to bid the same number of \( P_P \) to obtain license. For each increase in \( P_P \) the kink in the aggregate demand moves upward along \( D_0 \) and the terminus point of the in-state portion below the kink rises. In the example here the terminus point rises from $33.25 for 0 \( P_P \) to $37.63 for 2 \( P_P \) if \( r = .10 \) in year 1996. This is shown by \( D_1 \), \( D_2 \), and \( D_3 \). Equilibrium is attained in this illustration at the license price plus 2\( P_P \) where the quantity demanded equals \( S_j \), with out-of-state hunters getting \( Q_j/2 \) licenses and in-state hunters receiving the remainder.

There are two important points of this analysis. First, the preference point system further increases the misallocation of licenses from the straight price discrimination situation between in- and out-of-state hunters. While this might be politically more
acceptable within the state, it creates a larger welfare loss. In this example out-of-state hunters who were just willing to pay $253.25 are driven out of the market because the license requires them to pay $253.20 + 2PP. Second, the values that we get through using out-of-state expenditures or in-state expenditures in Equation 2 will not reveal the marginal value that would exist if licenses were sold outright. Figure 3 clearly shows that using in-state hunter expenditures in Equation 2 will reveal a marginal value that is less than the marginal value that would exist if out-of-state hunters were required to pay at least $253.25, and, beyond that, licenses were simply sold outright.\textsuperscript{16} However, the marginal values generated by in-state expenditures should reveal the relative preferences of all hunters as long as out-of-state hunter preferences do not differ substantially from in-state hunter preferences.

Using $T_{C_j}$ in Equation 2 as a measure of willingness-to-pay for license $j$, the next step is to hypothesize about how different hunting restrictions and herd attributes affect willingness-to-pay. Some attributes of hunting will have positive value and therefore should increase willingness-to-pay at the margin. For example, a higher probability of hunters harvesting an animal and low congestion are both likely to be valuable attributes. If the supply of license $j$ is fixed and hunters know their probability of success, a change in hunter success percentage should act to shift the demand for the license, causing a higher willingness-to-pay at the margin. The same can be said for lower congestion, higher likelihood of harvesting a trophy bull, higher likelihood of seeing game, greater

\textsuperscript{16} This is true as long as there are some out-of-state hunters willing to pay $253.25 for the license.
access to the site, and more allowable hunting days. Higher bull-to-cow ratios are expected to have a positive effect on the marginal value of bull hunts because they increase the probability of harvesting mature bull.\textsuperscript{17} On the other hand, all else equal, hunting restrictions such as only trophy animals, only archery, only muzzleloaders, only cows, or only bulls should negatively effect consumer valuation.\textsuperscript{18} Intuitively, added restrictions amount to reduced opportunities in the hunting activity. More specifically, assume initially that an individual is applying for permit $j$, which allows him to hunt elk in area $n$. Initially, permit $j$ has no restriction on the sex of animal or on the size antlers on the animal he can harvest or on the weapons he can use. It only constrains him to hunt in area $n$. Now assume the CDW decides to place an additional restriction on permit $j$ that says he is constrained to harvesting only brow-tined bulls. If the opportunity to harvest a spike bull or cow was not valued by him, it would not change his valuation of permit $j$. If on the other hand he did value the possibility of harvesting a non brow-tined bull or cow, the new restriction would reduce his valuation for permit $j$. By viewing changes in marginal valuations that occur because of restrictions, managers should be able to estimate how much regulations negatively impact hunter demand.

Due to data limitations controlling for all variables that might affect demand is impossible. Therefore, some restrictions on Colorado licenses may show a positive effect

\textsuperscript{17} For a discussion of why the specifics of elk reproduction imply that a higher bull-to-cow ratio indicates a higher probability of the herd containing mature bulls see Anderson and Hill (1995, 89-108).

\textsuperscript{18} At best restrictions will have no effect if they cover some attribute of hunting that is of zero value to the hunter. But, they can never have a positive effect.
on value because they often come with compensating differentials. For example, archery
hunts have very low congestion and a high number of permissible hunting days. If proper
control for all of these compensating differentials can not be obtained, they may make it
appear as though restrictions have a positive value. This will be discussed in more detail
in the context of the data.

The estimations will pay particular attention to the potential positive effect that
private sector supply of hunting opportunities can have on willingness-to-pay.

Colorado's Ranching for Wildlife Program was started as a three-year pilot program in
1986 and became permanent in 1989. In 1991 there were 20 wildlife ranches. Each of
these wildlife ranches “have a contract with the Division of Wildlife; an approved
wildlife management plan; an annual agreement about the number of animals to be
harvested by species and sex; an allocation of licenses between clients of the ranch and
‘public’ hunters selected by the lottery” (Anderson and Hill 1995, 116). The ranches are
allowed to sell their allocation of licenses to whomever at a market determined price.
The program is intended to encourage private landowners to set aside land or even to
stimulate investment in wildlife habitat by making owners a residual claimant of license
sales. By giving landowners market incentives, the CDW hoped that landowners would
improve hunting quality, not only for their clients but for public hunters as well. If these
ranches are doing their job by improving habitat and hunting quality, the private hunting
opportunities should positively affect willingness-to-pay of the public hunters. That is, a
publicly available licenses should be positively affected by the fact that the license
permits hunting on a wildlife ranch.
CHAPTER 4
DATA AND VARIABLES

The Data

Annual data for this analysis were obtained from the Colorado Division of Wildlife in the form Hunting Season Information (HSI) booklets for 1988-1996 and Big Game Hunting Statistics (BGHS) booklets for 1993-1996. The HSI booklets can be obtained for free each year at department stores, sporting good stores, or by mail from the CDW. Among other things the HSI booklets present information about hunting districts, season dates, applicable laws and regulations, fees, and method of selection in limited license hunts. The BGHS booklets act as an addendum to the HSI booklets. They can be purchased at department stores, sporting good stores, grocery stores, or through the CDW. They provide district specific information about the success percentage of hunters, number of PP required to enter each type of limited license drawing-as presented in Table 1, number of hunters present in each of the differing seasons, total harvest of elk by sex, and the bull-to-cow ratio of the relevant herd. The BGHS booklets also present a short regional forecast of big game hunting conditions for the upcoming season.
The Variables

The empirical equivalents to the theoretical variables are explained in this section. For the most part variables were taken directly from the BGHS booklets. However, in some cases the information from the booklets was adjusted to increase its accuracy.

The dependent variable in each of the estimations is a measure of opportunity cost from the number of preference points required to receive each of the licenses with certainty. For each of the different hunts, the BGHS booklets list the number of preference points required to have a random chance of obtaining any given license. One preference point greater than the amount required for a random chance is the amount needed to obtain any given license with certainty. Therefore one preference point was added to each preference point requirement listed.

Table 2 lists the dummy variables for each type of hunt except for late season hunts or either sex rifle hunts for which data was not available. The data permit estimating the value of early rifle season licenses only in years 1995 and 1996.

To achieve the most accurate measure of success (SUCC) for the differing hunts, some modification of those data presented in the BGHS was required. The modifications attempt to create a sex specific hunter success percentage, to create a unique hunter success percentage to correspond with the single preference point requirements reported by the CDW for the three separate rifle season hunts, and create a single hunter success percentage for licenses which permit hunting in more than one hunting district.
(1) To accurately estimate the effect hunter success percentage has on the marginal value of sex restricted licenses, a hunter success percentage specific to the sex of the elk was created. The percentage listed in the BGHS booklets is the percentage of both bull and cow hunters who were successful. For example, in 1996 district 76 had bull and cow license drawings for each of the three rifle seasons and the muzzleloader season, but the hunter success percentage that is listed for each of the seasons is the combined success percentage of both bull and cow hunters. For the archery only season this is not considered a problem since archery licenses are for either sex, so the success percentages listed are used directly in the estimations. Fortunately, the BGHS booklets also report how many bulls and cows were harvested in each district.

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>EARLY	extsubscript{j,t}</td>
<td>Dummy variable for the presence of an early season hunting only requirement on license ( j ) in year ( t ); either 0 or 1. It applies only to rifle hunts in 1995 and 1996 seasons.</td>
</tr>
<tr>
<td>WRANCH	extsubscript{j,t}</td>
<td>Dummy variable to indicate the license ( j ) hunt occurs on a Wildlife Ranch in year ( t ); either 0 or 1.</td>
</tr>
<tr>
<td>RCOW	extsubscript{j,t}</td>
<td>Dummy variable for a cow rifle elk license ( j ) in year ( t ); either 0 or 1.</td>
</tr>
<tr>
<td>AO	extsubscript{j,t}</td>
<td>Dummy variable for the presence of an archery only weapon requirement on license ( j ) in year ( t ); either 0 or 1.</td>
</tr>
<tr>
<td>MOB	extsubscript{j,t}</td>
<td>Dummy variable for a muzzleloader only weapon requirement on a bull license ( j ) in year ( t ); either 0 or 1.</td>
</tr>
<tr>
<td>MOC	extsubscript{j,t}</td>
<td>Dummy variable for a muzzleloader only weapon requirement on a cow license ( j ) in year ( t ); either 0 or 1.</td>
</tr>
</tbody>
</table>
for all three combined seasons and the muzzleloader season. Assuming that everyone who received a limited license hunted, separate hunter success percentages were created by dividing bull harvest in each district by available bull licenses and cow harvest by available cow licenses.  

2. The hunter success percentage for rifle hunts requires an additional consideration to deal with the lack of a set license supply for the three separate seasons: first, second, and third. The supplies of rifle season licenses are often allocated across the different seasons based on the proportion of hunters who apply for each of the separate seasons. For instance, in unit $j$ for year $t$, if there are ten cow licenses available for allocation between the second and third seasons, and sixty hunters applied for a license in the second season and forty applied for licenses in the third, the ten available licenses would be allocated proportionally: six for the second and four for the third (Colorado Big Game Hunting Statistics 1995). In this situation the BGHS booklets often present the PP required to receive the license as one number for multiple seasons. To permit the aligning of a unique preference point requirement with a unique hunter success percentage, the sum of elk harvested by sex over the respective seasons are divided by the total number of licenses allocated between them. For example, in 1996 district 24 is listed as requiring 2 PP to receive, with

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19This assumption does not always reveal what happens in reality, but the primary difference between the number of hunters that are present in each district and the number of licenses available occurs in those districts that have an unlimited number of bull permits available.

20In cases where a limited license permits hunting in more than one district harvest numbers from all of the districts were summed and divided by the total number of licenses available.
certainty, one of the 385 licenses allocated between the second and third combined season. Although there are actually two separate cow rifle hunts in district 24 (one in the second season and one in the third) this analysis will treat the two hunts as one and divide the sum of the harvest from both seasons by 385 to arrive at a single hunter success percentage. This procedure is used for every bull rifle and cow rifle season hunt in years 1993-1994. In 1995 and 1996 cow hunts were listed as season specific hunts in many cases. For these situations combining harvest numbers was not required to achieve an appropriate hunter success percentage, so separately listed hunts are treated as separate hunts.

3. Because some licenses permit hunting in more than one district, a single success percentage was created to express the success percentage of license holders. Some licenses permit the holder to hunt in more than one Game Management Unit. For instance, in 1996 there was a bull muzzleloader license that permitted hunters to hunt in district 57 and 58. However, the BGHS booklets have a separate success percentage for muzzle hunters in district 57 and 58. To obtain a success percentage that describes how successful holders of this license were, the total number of bulls harvested in both districts were summed and divided by the total number of licenses available.

There are some special considerations that must be given to hunter success percentage in the Wildlife Ranching hunts (WRANCH). The success of hunters in WRANCH is given in the BGHS booklets as the percentage of both private and public hunters who were successful. The thesis will treat the percentage of successful hunters in
both public and private hunts as the measure of hunter success percentage for the public
hunts. Conceptually, this will only be a problem if public hunter success percentage is
substantially different than that of the private hunter in the same area. The combined
measure is not a perfect indicator of public hunters’ probability of success, but it seems
reasonable that public hunters are likely view their on success probability as close to that
of all hunters on the ranch.

The bull-to-cow ratio (BRATIO) is expected to have a positive effect, all other
things equal, on the value of bull hunts. This variable is the number of bulls per 100
cows in each respected Game Management Unit. Each Game Management Unit has a
major elk herd, which in most cases is not unit specific. That is, many of the elk herds
inhabit more than one hunting unit. However, each unit does have one major herd that
the CDW uses to estimate the population and bull-to-cow ratio. The bull-to-cow ratio for
this herd is entered for bull hunts. For cow hunts the bull-to-cow ratio is not expected to
matter so zeros are entered for the bull-to-cow ratio.

The number of licenses available (NUMTAGS) is used to control for differences
in supplies that occur among the different hunts. Since this thesis is concerned with a
single equilibrium point on the demand curve for each hunt, all other things equal, the
number of licenses is expected to have a negative effect on marginal value. If the
downward sloping demand curves for two different hunts are the same, but the supply for
them is different, the one with the higher supply should show, all other things equal, a
lower marginal willingness-to-pay. To the extent that the empirical specification has
properly controlled for those factors that effect demand, this relationship should hold, and the sign on NUMTAGS should be negative.

In reality it is infeasible to control for all the factors that affect demand for differing limited licenses. This is precisely why Nickerson used dummy variables for each of the different Game Management Units in his specification. However, because the thesis makes annual cross sectional estimations among districts that often have only one type of limited hunt, district dummies are avoided. Many of the districts in the sample only have limited licenses for cow rifle hunts. Use of dummies in this case would cause much of the effect of cow rifle hunts on the value of licenses to be captured by them. Unfortunately, by not using the district dummies SUCC may capture those differences in demand that occur because of differences between districts such as accessibility, terrain, and distance from a major population center. Because success and these district specific variables will, presumably, always be highly correlated, trying to separate the effects by using district dummies may detract from the explanatory power of hunter success percentage. Nickerson explained this problem when his use of district dummies resulted in an insignificant effect of hunter success percentage on the expected value of a hunt.

The inability to control for the possible differences in hunt quality across different types of hunts may alter some of the sign predictions set forth in the theory chapter. All other things equal, weapon requirements such as archery only and muzzleloader only amount to restrictions that should reduce hunting opportunities from the liberal weapon requirements of rifle hunts and therefore reduce the marginal value of the license. Because these restricted hunts have their own respective benefits associated with them,
however, it is not certain that they represent reduced opportunities. The fact that archery and muzzleloader seasons occur at the height of the rut in September and early October, before limited license and unlimited license rifle hunts, may increase the opportunity to harvest a trophy bull or cow.\textsuperscript{21} Archery and muzzleloader hunts also are likely to have lower congestion. Because of these quality variables which cannot be controlled for, \textit{a priori}, the sign for weapon restrictions, AO, MOC, and MOB, can not be predicted. In the estimations the coefficients on AO, MOC, and MOB will reflect the value for each of the categories as a total "package" of hunt characteristics including a weapon restriction, the time of the year, and other characteristics.

Early season rifle hunts have many of the uncontrolled for compensating differentials particular to muzzleloader and archery hunts with no weapon restriction. Early rifle season hunts occur during the rut, and have low congestion as the weapon-restricted hunts do, but they do not have the reduction in range opportunities. Therefore, all other things equal, it is hypothesized that early rifle hunts will be more valuable than weapon restricted hunts. If the characteristics of low congestion and occurrence of the hunt during the rut are valuable, then, all other things equal, early season hunts should have a higher willingness-to-pay than regular rifle season hunts.

The lack of variability in the permissible number of hunting days among different hunts is another factor affecting our ability to accurately predict the sign of some

\textsuperscript{21} In addition an AO hunt permits the harvesting of either sex. Since all other types of hunts in the sample are sex specific, the either sex designation further confounds the assertion that an archery weapon requirement indicates reduced opportunities.
coefficients. The only meaningful variation in hunting days occurs between archery and all other types of hunts. Muzzleloader and rifle hunts all have about 10 hunting days, and archery hunts have 30 permissible hunting days. Because of the lack of variation, permissible hunting days is left out of estimations. Therefore, it is possible that the coefficients on the different types of hunts, particularly archery, include the effects of the number of hunting days.

Descriptive statistics of the variables are listed in Tables 3, 4, 5, and 6.  

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<td>1</td>
</tr>
</tbody>
</table>

22 The number of observations is greater in 1995 and 1996 because of reporting changes in the number of PP required for purchasing the regular season cow rifle licenses.
Table 4: Descriptive Statistics for Year 1995

<table>
<thead>
<tr>
<th>Year, 1995</th>
<th>n</th>
<th>Mean</th>
<th>Standard Dev.</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preference Points</td>
<td>227</td>
<td>2.33</td>
<td>2.04</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td>SUCC</td>
<td>227</td>
<td>0.31</td>
<td>0.22</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>NUMTAGS</td>
<td>227</td>
<td>128.25</td>
<td>162.16</td>
<td>1</td>
<td>1449</td>
</tr>
<tr>
<td>BRATIO</td>
<td>227</td>
<td>35.18</td>
<td>20.14</td>
<td>10</td>
<td>81</td>
</tr>
<tr>
<td>AO</td>
<td>227</td>
<td>0.08</td>
<td>0.27</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>MOB</td>
<td>227</td>
<td>0.12</td>
<td>0.32</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>MOC</td>
<td>227</td>
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<td>0.28</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
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<td>227</td>
<td>0.56</td>
<td>0.50</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>EARLY</td>
<td>227</td>
<td>0.02</td>
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<td>1</td>
</tr>
<tr>
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<td>0.11</td>
<td>0.31</td>
<td>0</td>
<td>1</td>
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</table>

Table 5: Descriptive Statistics for Year 1994

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<th>Year, 1994</th>
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<th>Mean</th>
<th>Standard Dev.</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
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<tr>
<td>Preference Points</td>
<td>148</td>
<td>2.30</td>
<td>2.07</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>SUCC</td>
<td>148</td>
<td>0.40</td>
<td>0.25</td>
<td>0</td>
<td>0.94</td>
</tr>
<tr>
<td>NUMTAGS</td>
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<td>190.36</td>
<td>257.11</td>
<td>1</td>
<td>1600</td>
</tr>
<tr>
<td>BRATIO</td>
<td>148</td>
<td>41.78</td>
<td>21.44</td>
<td>6</td>
<td>76</td>
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<tr>
<td>AO</td>
<td>148</td>
<td>0.08</td>
<td>0.27</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>MOB</td>
<td>148</td>
<td>0.14</td>
<td>0.35</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Year, 1994</td>
<td>n</td>
<td>Mean</td>
<td>Standard Dev.</td>
<td>Minimum</td>
<td>Maximum</td>
</tr>
<tr>
<td>-----------</td>
<td>-----</td>
<td>------</td>
<td>---------------</td>
<td>---------</td>
<td>---------</td>
</tr>
<tr>
<td>MOC</td>
<td>148</td>
<td>0.10</td>
<td>0.30</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>RCOW</td>
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<td>0</td>
<td>1</td>
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<td>0.37</td>
<td>0</td>
<td>1</td>
</tr>
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Table 6: Descriptive Statistics for Year 1993

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<th>Year, 1993</th>
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<th>Mean</th>
<th>Standard Dev.</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
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<tr>
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<td>1.98</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>SUCC</td>
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<td>0.36</td>
<td>0.22</td>
<td>0</td>
<td>1</td>
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<td>NUMTAGS</td>
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<td>220.75</td>
<td>320.72</td>
<td>1</td>
<td>1795</td>
</tr>
<tr>
<td>BRATIO</td>
<td>130</td>
<td>37.73</td>
<td>20.31</td>
<td>7</td>
<td>74</td>
</tr>
<tr>
<td>AO</td>
<td>130</td>
<td>0.10</td>
<td>0.30</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>MOB</td>
<td>130</td>
<td>0.16</td>
<td>0.37</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>MOC</td>
<td>130</td>
<td>0.11</td>
<td>0.30</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>RCOW</td>
<td>130</td>
<td>0.35</td>
<td>0.47</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>WRANCH</td>
<td>130</td>
<td>0.13</td>
<td>0.34</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>
CHAPTER 5

EMPIRICAL ESTIMATION AND RESULTS

The following statistical evaluation of the preference point allocation system allows us to measure hunters' marginal willingness-to-pay for various characteristics. The results are useful for assessing the value and distribution of licenses across different types of hunts, and they allow us to suggest potential improvements in the allocation of licenses and potential ways to increase revenue for the CDW.

Before proceeding to the specifics of how estimations were made and what the results imply, a summary of some issues addressed earlier is in order to provide a foundation for the empirical analysis. Marginal willingness-to-pay is measured by calculating the opportunity cost of obtaining a given license with certainty. The relevant costs include the outright price if the license and the cost of acquiring and holding preference points (PP). Equation 2 describes this cost. Certain characteristics of licenses are hypothesized in Chapter 3 and 4 to be important in determining hunters' willingness-to-pay. Characteristics that increase willingness-to-pay at the margin are the bull-to-cow ratio, wildlife ranch hunts, success percentage, and early rifle hunting.

\[ \text{Equation 2} \]

\[ \text{Based on the reason discussed in Chapter 3, licenses that required 0 PP to obtain with certainty are excluded from the regression analysis.} \]
Regressions analysis is used to estimate willingness-to-pay. All regressions use a linear functional form either in ordinary least squares (OLS) models or in ordered probit models.

The data were not pooled across years for several reasons. First, because PP build over time and requirements are constrained by the preference point starting date of 1984, there could be significant differences in calculated willingness-to-pay between the years. Second, the yearly regressions allow us to avoid making strong assumptions about the time series error process. Third, changes in how the CDW reported the data allow for more refined specification of the characteristics of licenses sold in 1995 and 1996.

**Functional Form**

There are many possible functional forms and estimation procedures that may be appropriate. A linear functional form with value as the dependent variable is used to allow straightforward interpretation of the coefficients. For example, the coefficients on the category dummy variables, i.e. archery and cow rifle, from OLS will indicate the average dollar value of an otherwise identical hunt. In addition there is no alternative model suggested by theory.

**Model Specification**

The basic model is given by Equation 3.

\[
VALUE_{jt} = \beta_{0t} + \beta_{1t}NUMTAGS_{jt} + \beta_{2t}BRATIO_{jt} + \beta_{3t}WRANCH_{jt} + \beta_{4t}AO_{jt} + \\
\beta_{5t}MOC_{jt} + \beta_{6t}RCOW_{jt} + \beta_{7t}SUCC_{jt} + \beta_{8t}EARLY_{jt} + \varepsilon_{jt}
\]

(3)
Where \( j \) is the license defined by hunting area and characteristics of the license, and \( t \) is the year in which the license is purchased.

The dependent variable is defined as follows:

\[
\text{VALUE} = \text{the value of each license as generated through Equation 2 using in-state hunter expenditures. A sensitivity analysis is carried out over a number of different values for } r.
\]

The independent variables are defined as follows:

\[
\begin{align*}
\text{NUMTAGS} &= \text{number of licenses available} \\
\text{BRATIO} &= \text{number of bulls per 100 cows for all bull licenses} \\
\text{WRANCH} &= \text{Dummy variable to indicate a Wildlife Ranch in; either 0 or 1.} \\
\text{AO} &= \text{Dummy variable for the presence of an archery only weapon requirement on an either sex license; either 0 or 1.} \\
\text{MOC} &= \text{Dummy variable for the presence a muzzleloader only weapon restriction on a cow license; either 0 or 1.} \\
\text{MOB} &= \text{Dummy variable for the presence a muzzleloader only weapon restriction on a bull license; either 0 or 1.} \\
\text{RCOW} &= \text{Dummy variable for the presence of no weapon restriction on a cow license; either 0 or 1.} \\
\text{SUCC} &= \text{the percentage of hunters with license } j \text{ who are successful in year } t. \\
\text{EARLY} &= \text{Dummy variable for the presence of an early season hunting designation on a rifle license; either 0 or 1.}
\end{align*}
\]

There are several characteristics of the model and data that must be considered when interpreting the estimates. First, because the bull rifle dummy is suppressed, the intercept term takes on the coefficient associated with bull rifle licenses, and it serves as the base or benchmark to which the other categories are compared. All other dummy
variable coefficients will indicate the extent to which their respected categories differ in marginal value from bull rifle hunts. Second, the model assumes that the effect of changes in supply is the same for every hunt. In other words the slope of the linear demand curve for every different license is identical, and the coefficient on NUMTAGS will indicate the slope of all demand curves. Further, the structure of the model corrects for differences in supply through NUMTAGS. This is important because under this specification the only way that differences in marginal value can be observed is through characteristics that shift demand. For the marginal value of some category to differ from the intercept (bull rifle hunts), the demand for the average hunt within the category must be shifted in or out from bull rifle hunts. If different types of hunts were placed randomly throughout the state, a higher marginal value for a given category of license type, represented by a significantly positive coefficient on the respective category variable, would indicate that demand for that type of hunt was higher than demand for other types of hunts. With random placement throughout the state we could be fairly certain that all other factors that affect demand would be the same across different types of hunts. In reality, however, it is not likely that different types of hunts are placed randomly. In this case a significantly positive coefficient will indicate that demand for the package of characteristics that are contained within a category is higher.

**OLS Results**

The results of the OLS estimations are listed by year in Tables 4, 5, 6, and 7. The coefficient on the intercept indicates the average marginal value of bull rifle licenses if all
other variables are 0. The remaining value of a bull rifle hunt comes from three other
variables (NUMTAGS, BRATIO, and SUCC) that describe attributes of the hunt. To get
a full in-state marginal value for a bull rifle license that has average characteristics, we
can use the averages from Table 3 into the regression equation.

\[ \text{Value} = \beta_0 + \beta_{1t} \text{NUMTAGS}_{jt} + \beta_{2t} \text{BRATIO}_{jt} + \beta_{8t} \text{SUCC}_{jt} \]

For example, in 1996 where \( r = .10 \),
\[ \text{Value} = 32.98 + (123.87)(-0.0007) + (36.41)(.204) + (41)(.076) = $43.43 \]
Equation 4 gives the marginal value of a bull rifle license to in-state hunters given the
readily available substitute of over the counter unlimited bull rifle licenses. Even where
the estimate of \( b_0 \) is the highest, year 1995 where \( r = .12 \), the estimated value from
Equation 4 for a bull rifle hunt with average characteristics is only $43.20, a value much
lower than the infra-marginal average value estimates found by Hay (1988) using
contingent valuation. Hay (1988) found that hunters were willing to pay $40.00 more per
day than they were required to. If the average hunter hunts for 3 days, Hay’s estimates
would indicate that the average hunter would be willing to pay $120.00 more for the
privilege than that which he is required to pay. Here we see that for limited license hunts
the value of a bull rifle license with average characteristics to the marginal person is
much lower. This indicates that managers can not rely on infra-marginal average values
in pricing limited elk licenses if they continue to offer unlimited bull licenses, that searve
as substitutes, and they expect to sell all of the available supply.

As expected, the success percentage of hunters has a positive and significant
effect on the marginal value of elk hunts for every year in the sample and for any \( r \). This
result differs from those in Nickerson (1990). Nickerson (1990) found that hunter success percentage had no significant effect on the expected value of elk licenses. Perhaps the results differ because the model in Equation 3 excludes the district dummies. The proper interpretation of the coefficient on SUCC is that the marginal consumer is willing to pay between $0.06 and $0.13, depending on year and $r$, for a one-percent increase in success. The similarity of the parameter estimates across years suggests that effect of success on the marginal value of limited elk licenses is relatively constant over time.

The interpretation of the estimated parameter for bull muzzleloader licenses depends on the year considered. Higher marginal willingness-to-pay, relative to bull rifle licenses, is suggested for these hunts in 1993 and 1994. Bull muzzleloader licenses were effectively being purchased for between $4.33 and $6.71 more than bull rifle licenses, depending on year and $r$. By increasing the number of bull muzzleloader licenses available, social welfare and revenue to the CDW could have been increased at the margin after adjusting for differences in success percentage. From an economic efficiency standpoint the number of licenses allocated to bull muzzleloader hunts, as opposed to bull rifle or archery, should be increased until willingness-to-pay at the margin between muzzleloader and other types of bull hunts are equal. An important caveat in this interpretation is that there is no control for the types of elk harvested, and this may be important in maintaining the overall health of the herd. In other words, although the number of elk taken can be held constant by accounting for success percentage in policy changes, allocating more bull licenses to muzzleloader hunts may
result in a higher percentage of mature bulls being harvested because these hunts occur
during the rut. The extra harvest of mature bulls may cause a decline in herd health,
which in the long run may cause marginal willingness-to-pay to fall. However, if health
is not changed, more muzzleloader hunts should have been offered. One can gather from
the results that in 1993 and 1994 the losses in opportunities to harvest

Table 7: OLS Results, 1996

<table>
<thead>
<tr>
<th>Parameters Estimated 1996</th>
<th>Base Results (t-stat)</th>
<th>* = significant at .10</th>
<th>** = significant at .05</th>
<th>*** = significant at .01</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dependent Var. = Value</td>
<td></td>
<td>N = 215</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Value when</td>
<td>r = .06</td>
<td>r = .08</td>
<td>r = .10</td>
<td>r = .12</td>
</tr>
<tr>
<td>INTERCEPT</td>
<td>33.46 (14.58)***</td>
<td>33.26 (12.77)***</td>
<td>32.98 (11.17)***</td>
<td>32.61 (9.75)***</td>
</tr>
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<td>-0.006 (-1.58)</td>
<td>-0.007 (-1.53)</td>
<td>-0.007 (-1.49)</td>
<td>-0.008 (-1.45)</td>
</tr>
<tr>
<td>BRATIO</td>
<td>0.127 (3.97)***</td>
<td>0.149 (4.1)***</td>
<td>0.17 (4.26)***</td>
<td>0.204 (4.37)***</td>
</tr>
<tr>
<td>WRANCH</td>
<td>11.78 (6.25)***</td>
<td>13.33 (6.23)***</td>
<td>15.07 (6.21)***</td>
<td>17.02 (6.19)***</td>
</tr>
<tr>
<td>AO</td>
<td>3.42 (1.4)</td>
<td>3.69 (1.33)</td>
<td>3.97 (1.26)</td>
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<td>MOB</td>
<td>2.07 (1.09)</td>
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<td>-0.79 (-0.301)</td>
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</tbody>
</table>
### Table 8: OLS Results, 1995

<table>
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<tr>
<th>Parameters Estimated 1995</th>
<th>Base Results (t-stat)</th>
<th>* = significant at .10</th>
<th>** = significant at .05</th>
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<td>INTERCEPT</td>
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<td></td>
<td>(16.67)***</td>
<td>(14.92)***</td>
<td>(13.56)***</td>
<td>(11.96)***</td>
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<td>-0.003</td>
<td>-0.003</td>
<td>-0.004</td>
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<tr>
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<td>(-1.082)</td>
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<td>(-0.99)</td>
<td>(-0.94)</td>
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<tr>
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<td>-0.012</td>
<td>-0.008</td>
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<td>0.003</td>
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<td>(0.052)</td>
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<td>8.68</td>
<td>9.99</td>
<td>11.48</td>
<td>13.16</td>
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<td></td>
<td>(4.97)***</td>
<td>(5.03)***</td>
<td>(5.06)***</td>
<td>(5.10)***</td>
</tr>
<tr>
<td>AO</td>
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<td></td>
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<td>-2.55</td>
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<td>-3.49</td>
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<tr>
<td></td>
<td>(-1.11)</td>
<td>(-1.15)</td>
<td>(-1.18)</td>
<td>(-1.21)</td>
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<tr>
<td></td>
<td>2.08</td>
<td>2.12</td>
<td>2.14</td>
<td>2.12</td>
</tr>
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<td>(1.14)</td>
<td>(1.024)</td>
<td>(.905)</td>
<td>(0.79)</td>
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<td></td>
</tr>
<tr>
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<td>-5.66</td>
<td>-6.22</td>
<td>-6.81</td>
<td>-7.43</td>
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<tr>
<td></td>
<td>(-2.11)**</td>
<td>(-2.03)**</td>
<td>(-1.95)*</td>
<td>(-1.87)*</td>
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</table>
### Parameters Estimated 1995

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<tr>
<th>Dependent Var. = Value</th>
<th>Base Results (t-stat)</th>
<th>* = significant at .10</th>
<th>** = significant at .05</th>
<th>*** = significant at .01</th>
<th>N = 224</th>
</tr>
</thead>
<tbody>
<tr>
<td>RCOW</td>
<td>-7.83 (-3.45)***</td>
<td>-8.63 (-3.33)***</td>
<td>-9.49 (-3.22)***</td>
<td>-10.40 (-3.09)***</td>
<td></td>
</tr>
<tr>
<td>SUCC</td>
<td>0.09 (3.82)***</td>
<td>0.10 (3.70)***</td>
<td>0.11 (3.58)***</td>
<td>0.12 (3.46)***</td>
<td></td>
</tr>
<tr>
<td>EARLY</td>
<td>16.86 (4.65)***</td>
<td>19.58 (4.74)***</td>
<td>22.68 (4.81)***</td>
<td>26.19 (4.88)***</td>
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<tr>
<td>Adjusted $R^2$</td>
<td>0.5577</td>
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</table>

### Table 9: OLS Results, 1994

<table>
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<tr>
<th>Dependent Var. = Value</th>
<th>Base Results (t-stat)</th>
<th>* = significant at .10</th>
<th>** = significant at .05</th>
<th>*** = significant at .01</th>
<th>N = 146</th>
</tr>
</thead>
<tbody>
<tr>
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<td>$r = .08$</td>
<td>$r = .10$</td>
<td>$r = .12$</td>
<td></td>
</tr>
<tr>
<td>INTERCEPT</td>
<td>40.61 (13.93)***</td>
<td>41.32 (12.52)***</td>
<td>42.05 (11.27)***</td>
<td>42.79 (10.16)***</td>
<td></td>
</tr>
<tr>
<td>NUMTAGS</td>
<td>0.002 (0.60)</td>
<td>0.002 (0.618)</td>
<td>0.002 (0.634)</td>
<td>0.002 (0.65)</td>
<td></td>
</tr>
<tr>
<td>BRATIO</td>
<td>-(0.05) (-1.14)</td>
<td>-0.052 (-1.07)</td>
<td>-0.054 (-0.97)</td>
<td>-0.056 (-0.89)</td>
<td></td>
</tr>
<tr>
<td>WRANCH</td>
<td>8.11 (4.21)***</td>
<td>9.12 (4.18)***</td>
<td>10.24 (4.15)***</td>
<td>11.47 (4.12)***</td>
<td></td>
</tr>
<tr>
<td>AO</td>
<td>-0.56 (-.25)</td>
<td>-0.67 (-0.27)</td>
<td>-0.81 (-0.29)</td>
<td>-0.98 (-0.30)</td>
<td></td>
</tr>
<tr>
<td>MOB</td>
<td>4.33 (2.20)**</td>
<td>4.79 (2.15)**</td>
<td>5.27 (2.09)**</td>
<td>5.81 (2.04)**</td>
<td></td>
</tr>
<tr>
<td>Parameters Estimated 1994</td>
<td>Base Results (t-stat)</td>
<td>* = significant at .10 ** = significant at .05 *** = significant at .01 N = 146</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------------------</td>
<td>------------------------</td>
<td>------------------------------------------------------------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dependent Var. = Value</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MOC</td>
<td>-6.23 (-1.97)**</td>
<td>-6.79 (-1.90)*</td>
<td>-7.38 (-1.83)*</td>
<td>-7.99 (-1.75)*</td>
<td></td>
</tr>
<tr>
<td>SUCCEED</td>
<td>0.089 (3.50)***</td>
<td>0.10 (3.48)***</td>
<td>0.11 (3.45)***</td>
<td>0.13 (3.42)***</td>
<td></td>
</tr>
<tr>
<td>Adjusted $R^2$</td>
<td>0.5333</td>
<td>0.5267</td>
<td>0.5199</td>
<td>0.5129</td>
<td></td>
</tr>
</tbody>
</table>

**Table 10: OLS Results, 1993**

<table>
<thead>
<tr>
<th>Parameters Estimated 1993</th>
<th>Base Results (t-stat)</th>
<th>* = significant at .10 ** = significant at .05 *** = significant at .01 N = 128</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dependent Var. = Value</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Value when</td>
<td>r = .06</td>
<td>r = .08</td>
</tr>
<tr>
<td>INTERCEPT</td>
<td>34.62 (14.61)***</td>
<td>34.61 (13.04)***</td>
</tr>
<tr>
<td>NUMTAGS</td>
<td>0.0011 (0.64)</td>
<td>0.002 (0.67)</td>
</tr>
<tr>
<td>BRATIO</td>
<td>0.01 (0.30)</td>
<td>0.016 (0.37)</td>
</tr>
<tr>
<td>WRANCH</td>
<td>9.00 (5.11)***</td>
<td>10.08 (5.11)***</td>
</tr>
<tr>
<td>AO</td>
<td>0.46 (0.24)</td>
<td>0.50 (0.24)</td>
</tr>
<tr>
<td>MOB</td>
<td>4.95 (2.92)***</td>
<td>5.49 (2.90)***</td>
</tr>
</tbody>
</table>
because of range limitations were, at the margin, less detrimental to demand than the
benefits of lower congestion, increased hunting days, and time of year in which the hunt
occurred. In 1995 and 1996 the results do not indicate that willingness-to-pay could have
been increased by allocating more bull limited licenses to muzzleloader hunts. In these
years the coefficient on bull muzzleloader hunts is not significant.

As with bull muzzleloader licenses, the results for cow muzzleloader licenses vary
by year. For the years in which the coefficient is significant, they are yielding between
$5.66 and $7.99 less than bull rifle licenses at the margin.

Cow rifle licenses also have a significant negative effect on the value of licenses
at the margin for every year except 1996, and because of the structure of the model, this
result can only be from a lower level of demand for cow rifle licenses than for bull rifle
licenses. Cow rifle licenses effectively sell for between $4.90 and $15.63 less than bull
rifle licenses do. The magnitude of this effect differs considerably depending on year and

<table>
<thead>
<tr>
<th>Parameters Estimated 1993</th>
<th>Base Results</th>
<th>* = significant at .10</th>
<th>** = significant at .05</th>
<th>*** = significant at .01</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dependent Var. = Value</td>
<td>(t-stat)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MOC</td>
<td>1.79 (0.68)</td>
<td>2.12 (0.72)</td>
<td>2.51 (0.76)</td>
<td>2.94 (0.80)</td>
</tr>
<tr>
<td></td>
<td>-4.90 (-2.26)**</td>
<td>-5.31 (-2.20)**</td>
<td>-5.75 (-2.12)**</td>
<td>-6.20 (-2.05)**</td>
</tr>
<tr>
<td>SUCG</td>
<td>0.09 (3.42)***</td>
<td>0.10 (3.45)***</td>
<td>0.11 (3.49)***</td>
<td>0.13 (3.52)***</td>
</tr>
<tr>
<td>Adjusted R²</td>
<td>0.4879</td>
<td>0.4866</td>
<td>0.4848</td>
<td>0.4827</td>
</tr>
</tbody>
</table>
The result here that cow rifle hunts have a significant negative on marginal value differs from Nickerson (1990) who found that restricting hunters to bagging only antlerless animals did not significantly affect license demand. Nickerson used his findings to suggest that information gathered at public hearings, where hunting policy input is dominated by representatives of well organized hunting-clubs, is not an accurate reflection of hunters as a whole. As he states, at these meetings "hunting-club representatives often argue that they do not want antlerless-only hunts" (Nickerson 1990, 446). The estimations made here do not support Nickerson's conclusion regarding these meetings.

The parameters for archery hunts are not significant in any estimation. This suggests that managers are efficiently allocating licenses between bull rifle hunts and archery hunts, thus keeping marginal willingness-to-pay about the same.

The fact that the bull-to-cow ratio is significant and positive only in year 1996 implies that hunters do not appear to use bull-to-cow ratio as an indicator of their likelihood of harvesting a mature bull. Perhaps this ratio is not very important from the hunters perspective. This result says that managers in the Colorado Division of Wildlife probably can not affect their revenue by much through reallocating licenses differently based the bull-to-cow ratios.

There could, however, be a confounded variable problem occurring that affects the calf estimate on the bull-to-cow ratio. Bull-to-cow ratio may be systematically related to terrain and the amount of private land contained within a given GMU. For example, consider two districts that only differ because of terrain, where one contains dense forest
and the other is sparsely forested. We might expect that the higher bull-to-cow ratio will be in the densely forested unit because mature bulls make use of the cover to hide. For this explanation to make sense mature bulls would have to be relatively better at making use of cover than immature bulls and cows are, a commonly held view by hunters. Our inability to control for these differences among districts may lead to the insignificant bull-to-cow ratio result.

As hypothesized, early season rifle permits are significantly positive for every year in the sample. As well, early season rifle hunts elicit a higher willingness-to-pay than weapons restricted hunts. These early season rifle hunts exhibit an increased willingness-to-pay from consumers because they combine many of the beneficial qualities of archery and muzzleloader hunts with the advantage of harvesting an animal at a longer range when using a high powered rifle. This result indicates that the CDW could increase revenues by allocating more bull rifle hunts to the early season. Once again, however, managers would have to control for success percentage differences and consider the long-term effects on herd health.

Hunts occurring on wildlife ranches had a significantly positive effect on the marginal value of licenses in all years. Because hunters were willing to pay significantly more for hunts that occurred on wildlife ranches with other variables held constant, it appears that wildlife ranches do improve hunting quality for public hunters. Most likely

24 The differences in the ability to use cover are likely due to mature bulls propensity to travel alone rather than with the herd. A herd of 50 elk are much easier to spot and track than are single or pairs of bulls.
this increased marginal willingness-to-pay is the result of a higher probability of harvesting a trophy bull. Perhaps this is due to habitat enhancement and game management on these private lands. However, the increased willingness-to-pay could imply that wildlife ranches are typically in areas where there is relatively higher quality hunting to begin with. If wildlife ranches are established in areas with relatively higher quality elk stock and habitat, increased willingness-to-pay may not be the result of differing private management practices.

The results of the OLS regression are for the most part as hypothesized. However, the estimates can rightfully be brought under criticism for several reasons. First, the dependent variable in all of the estimations is not continuous. Each license takes on a single value that is associated with the number of preference points (PP) required to acquire the license with certainty. The largest variability in the number of PP required to obtain limited licenses was in 1996 where the number ranged from 1 to 12. This means that for any year there was a maximum of 12 different values for the dependent variable. Second, for every year, about half of the licenses only require one preference point. Having such a large portion of the sample made up of the lowest value may bias the parameter estimates. To account for these problems an ordered probit model is used.

**Ordered Probit Estimates**

The ordered probit model is common for analyzing problems in which the dependent variable is discrete and inherently ordered (Greene 1997). It is appropriate
here because, although value is discrete, it is ordinal. That is, the value associated with 9 PP is more valuable than that associated with 8 PP and so on. Because the ordered probit model treats the dependent variable as an ordinal ranking of preference, it makes no difference whether value or PP is used as the dependent variable. Therefore, PP are used for simplicity as the dependent variable. The only detriment to using the probit procedure is that the interpretation of the parameter estimates is no longer in dollars. Instead we get the likelihood that certain characteristics will increase or decrease marginal willingness-to-pay through PP.

The ordered probit procedure is built around a latent regression that would exist if the dependent variable were observable as continuous rather than discrete. Suppose there is an underlying continuous function $y^*$ that is related to the underlying and continuous willingness-to-pay. Specifically

$$y^* = X\beta + \varepsilon$$

where $y^* = \text{continuous amounts of PP}$.

However, we do not observe $y^*$, but rather we observe is

$$PP = 1 \text{ if } y^* \leq 0.$$  
$$PP = 2 \text{ if } 0 < y^* \leq \mu_1.$$  
$$PP = 3 \text{ if } \mu_1 < y^* \leq \mu_2.$$  
$$\vdots$$  
$$PP = t \text{ if } \mu_{t-1} < y^*.$$
The \( \mu \)'s are unknown threshold parameters to be estimated with \( \beta \). We do not know the distribution of \( y^* \), but we can evaluate the distribution of \( \epsilon \). Assuming a form for the distribution of \( \epsilon \) will allow the development of the probabilities for \( y \) landing in the various categories of preference point requirements. Where \( \epsilon \) is normally distributed, \( F \) is the cumulative normal distribution, \( X \) is the matrix of explanatory variables, and \( \beta \) is the vector of coefficients, we have the following probabilities:

\[
\begin{align*}
\text{Prob}(y = 1) &= \text{Prob}(X\beta + \epsilon \leq 0) \\
&= \text{Prob}(\epsilon \leq -X\beta) \\
&= F(-X\beta)
\end{align*}
\]

\[
\begin{align*}
\text{Prob}(y = 2) &= \text{Prob}(\text{PP} = 2 \text{ or } 1) - \text{Prob}(\text{PP} = 1) \\
&= \text{Prob}(X\beta + \epsilon \leq \mu_1) - F(-X\beta) \\
&= \text{Prob}(\epsilon \leq \mu_1 - X\beta) - F(-X\beta) \\
&= F(\mu_1 - X\beta) - F(-X\beta)
\end{align*}
\]

\[
\begin{align*}
\text{Prob}(y = 3) &= \text{Prob}(\text{PP} = 3, 2 \text{ or } 1) - \text{Prob}(\text{PP} = 2 \text{ or } 1) \\
&= \text{Prob}(X\beta + \epsilon \leq \mu_2) - F(\mu_1 - X\beta) \\
&= \text{Prob}(\epsilon \leq \mu_2 - X\beta) - F(\mu_1 - X\beta) \\
&= F(\mu_2 - X\beta) - F(\mu_1 - X\beta)
\end{align*}
\]

All other probabilities for \( y \) can be developed in a similar manner.\(^25\) For all probabilities to be positive, we must have

\[
0 < \mu_1 < \mu_2 < \mu_3 < \ldots < \mu_{k-1}.
\]

These \( \mu \) terms give us the thresholds for each PP category. Explanatory variables enter the ordered probit model through a stochastic process. For example, a desirable characteristic such as success is hypothesized to have a positive coefficient. As success

\(^25\) Much of the discussion here and more detailed information about the ordered probit model is found in Greene (1997).
increases and all else is equal, $X\beta$ increases and $F(-X\beta)$ decreases. Through this framework, an increase in a favorable characteristic will decrease the likelihood of the lowest PP rank, subsequently increasing the likelihood of the higher ranks.

The results of the probit procedure are listed in Table 8 and do not differ substantially from the OLS results. Although the level of significance varies, most of the

<table>
<thead>
<tr>
<th>Table 11: Ordered Probit Results</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Parameters Estimated</strong></td>
</tr>
<tr>
<td><strong>Dependent Var. = Preference Points</strong></td>
</tr>
<tr>
<td>INTERCEPT</td>
</tr>
<tr>
<td>NUMTAGS</td>
</tr>
<tr>
<td>BRATIO</td>
</tr>
<tr>
<td>WRANCH</td>
</tr>
<tr>
<td>AO</td>
</tr>
<tr>
<td>MOB</td>
</tr>
<tr>
<td>MOC</td>
</tr>
<tr>
<td>RCOW</td>
</tr>
</tbody>
</table>
factors that are significant in the OLS regression are again significant in the ordered probit. The main differences between the two procedures occur where a variable was not significant in OLS and becomes significant in ordered probit. Where differences do occur, the results of the probit procedure are probably more reliable because it appropriately handles the discontinuous variables problems in OLS that were pointed out above.

Most of the interpretations of the OLS results are supported by the ordered probit procedure. Success percentage is significantly positive. The results also support the hypotheses that wildlife ranching hunts increase willingness-to-pay. If a given license permits hunting on a wildlife ranch, it is more likely that the hunt will command more PP. Early season rifle licenses are again positive and significant.

Where there are differences in the ordered probit and OLS, they still tend to support the interpretations made above. The fact that bull-to-cow ratio is not significant in any year further supports the interpretation made from OLS. Again, the bull-to-cow ratio does not seem to indicate to hunters that a given herd is more likely to contain more
accessible mature bulls. Using the ordered probit, bull muzzleloader licenses are significant for three out of four years. It appears that there is excess marginal willingness-to-pay that could be captured if more limited bull licenses were allocated towards muzzleloader hunts, provided that differences in success rates and long term herd effects are considered. This statement has additional merit because Game Management Units that contain limited bull rifle licenses tend to be the same areas that contain limited bull muzzleloader licenses. Although archery hunts are significant for year 1996 in the ordered probit, significance in only one out of four years tends to support the conclusions from the OLS estimations. The probit results further supports the conclusion that cow rifle licenses are worth less than bull rifle licenses.

In summary the empirical results support the conclusion that willingness-to-pay is systematically related to quality variables such as lower congestion and a higher probability of harvesting a mature bull. The implication is that efficiency and revenue to the CDW may be increased by reallocating licenses from marginally lower valued characteristics to marginally higher ones if reallocation is not costly. For example, increasing the number of muzzleloader bull licenses and the number of early season licenses makes good economic sense provided it does not adversely effect long term herd health. On the other hand it appears that there is an approximately optimal allocation of archery licenses.
CHAPTER 6

CONCLUSION

The purpose of the thesis was to develop a method of assessing the marginal values for limited elk hunting licenses in Colorado and to estimate marginal values of hunt characteristics. A new measure was constructed to calculate willingness-to-pay at the margin. Rather than relying on travel costs, surveys, or expected values to find this marginal value, the new measure used hunters' opportunity costs of securing elk licenses in Colorado. The effects of Colorado's preference point system on the distribution of licenses between in-state and out-of-state hunters were evaluated. Hunting attributes were evaluated, and their hypothesized effects on demand were given. The statistical inquiry suggests changes in license allocation to increase both revenue to the Colorado Division of Wildlife and social welfare. The analysis revealed marginal values, as opposed to average values given by alternative methods such as contingent valuation or travel cost, that are a more accurate indicator of how much licenses can be sold for. Higher willingness-to-pay was closely linked to unmeasurable quality variables such as low congestion and a higher probability of harvesting a mature bull. Also, the results gave substantial differences from similar studies regarding the factors that affect limited elk license demand.
Suggestions for Further Research

The statistical evaluation completed in this study could be extended with additional data. Measures of the accessibility of Game Management Units and measures of the characteristics of animals harvested would allow more accurate modeling of the effects of each on marginal value. Information about other factors that effect demand such as hunter income, prices of available substitutes, and the costs of travel would permit a hedonic study on the demand for hunting attributes.

Similar studies to the one here could be done for other species in Colorado. Deer and antelope hunting licenses are allocated in roughly the same manner. Such studies could compare the attributes that effect elk license demand effect with other big game license demand.

Similar studies to this could be done using the marginal values that come from the use of Nickerson's model (1990). From his model, as shown in Chapter 3, it is possible to generate marginal values for hunting licenses in states that use random lotteries.

States are increasingly turning to quasi-market mechanisms to allocate wildlife permits. After a thorough analysis and careful modeling of these mechanisms, the programs offer a wealth of information about marginal values of hunting characteristics. These marginal values are crucial for resource allocation decisions by state game agencies and give important benchmarks for the private provision of hunting opportunities.
BIBLIOGRAPHY
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