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Economic Analysis of Choice Behavior: Incorporating Choice Set Formation, Non-compensatory Preferences and Perceptions into the Random Utility Framework

by

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ABSTRACT

The Random Utility Model has become the dominant empirical model used in environmental valuation and other areas of consumer demand analysis involving the choice of discrete items. This thesis investigates in detail three assumptions of the Random Utility Model. It consists of three studies that either propose or evaluate methods of relaxing the common assumptions. The first study examines models of choice set formation – the determination of the set from which consumers make a choice. It compares a fully endogenous choice set formation model, called the Independent Availability Logit model (Swait, 1984), to the implicit availability function approach (Cascetta and Papola, 2001) that approximates choice set formation. The second study proposes an analytical model that incorporates non-compensatory preferences in the framework of the Random Utility Model. The proposed model allows for the estimation of "cutoffs" – the levels an attribute must satisfy or the alternative will not be chosen or will be penalized – without prior information about these levels. The third study explores structural models that allow for subjective perceptions of attributes.

We find that models with choice set formation are better at capturing choice behavior compared to standard random utility models. The choice set formation process also

affects welfare measures, indicating that ignoring choice set formation may result in biased welfare estimates. The proposed method to estimate cutoff levels in the second study appears to work well with synthetic data, however it is more challenging when applied to real data. We find that it is important to include cutoff information in empirical analysis, and that the results differ from models that use self-reported cutoffs. In the third study, we find that subjective perception plays a significant role in the decision making process.

The thesis also provides some policy relevant information. The first study provides estimates of welfare measures for recreationists where wildlife is affected by Chronic Wasting Disease. The second study provides estimates of the willingness to pay for endangered species conservation. And the third study provides new estimates of the values of risk aversion when subjective perceptions on probabilities of choice are incorporated into the analysis.

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CHAPTER 1: INTRODUCTION

The theory of individual choice, which attempts to explain the economic behavior of choice among discrete alternatives, has been applied to a variety of issues. The theory was first applied to transportation demand, particularly the choice among transportation modes (Swait, 1984). It was then found to provide a tractable model for analyzing choice behavior in other fields. In environmental valuation, it has been applied to choice data generated in markets (actual choices or Revealed Preference data), and data arising from hypothetical markets or choices (Stated Preference data) (Bockstael and McConnell, 2007). The theory has also been applied to experimental economic data on respondents' choices among options, which is one of the methods used to analyze choice under risk and uncertainty (Harrison and Rutström, 2008). Other fields of application of individual choice theory include choice of technology adoption, choice of crops, fuel, participation in conservation programs and health risk reductions (Bockstael and McConnell, 2007).

The theory of individual choice was developed based on principles of psychology, particularly the Law of Comparative Judgment of Thurstone (1927). In this theory, individuals react to stimuli. When choosing among alternatives, individuals tend to choose the alternative with the highest perceived level of stimulus, which comprises its objective level and a random error. This stimulus is interpreted by economists as the level of satisfaction or utility, which is equal to a systematic plus a random component

(Marschak, 1960, Manski, 1977). The choice decision then complies with standard economic theory: individuals choose the alternative with the highest level of utility. This is the basic idea of the Random Utility Model (RUM).

Today the RUM is the dominant paradigm used in understanding how people make choices. The specification of a random and a systematic component of utility allows for the econometric analysis of choices to estimate parameters of preference for multidimensional goods. Because the random component of utility is unknown to analysts, the model becomes probabilistic. Instead of identifying the chosen option, it predicts the probability of each alternative being chosen. The RUM was made popular by McFadden (1978) through several models including the multinomial logit model (MNL – which assumes a Gumbel distribution error), the nested logit model and the generalized extreme value (GEV) model. In these models, utility is specified as a function of attributes of the alternatives under consideration.

The simplest RUM is based on several assumptions, including Independence of Irrelevant Alternatives (IIA), an additive error, homogeneous preferences and a homogeneous scale. The assumptions of IIA introduced by Luce (1959) states that the ratio of choice probabilities of two alternatives must be the same for every choice set that includes them. In other words, the ratio must be unchanged when one or more alternatives are included or excluded from the choice set. Choice models may produce biased estimates if IIA fails. The assumption of an additive error requires that the error term is additive to the systematic component of utility. In addition, a specific distribution of the error term has to be assumed. Homogenous preferences imply that individuals have identical utility functions. Homogenous scale means that the variance of the random error is identical for all individuals.

In addition to these assumptions, a typical application of RUM usually employs several additional assumptions. First, the choice set, or the set of alternatives that individual decision makers choose from, must be known and fixed. In the case of stated preference methods, researchers present a designed set of alternatives to respondents and ask for a choice (Grafton *et al*., 2003). In some cases of revealed preference methods, for example recreational site choice, researchers define the alternatives of a site using rules such as distance (Parsons and Hauber, 1998). Second, it is usually assumed that utility is a linear function of alternatives' attributes, implying a compensatory preference structure. The assumption of compensatory preferences implies that a change in one attribute can be compensated for by a change in another attribute. Finally, it is usually assumed that there is no difference between the attribute levels perceived by the individual and those used by the researchers. In other words, individuals are assumed to be using the same attribute levels that the researcher is using in making their decisions, whether these are objective measures of attributes collected by the researcher or attributes as presented to the respondent by the researcher in an experiment or stated preference task. This assumption rules out the possibility that perceptions differ from objective measures.

The basic structure of the RUM has been expanded in many ways relaxing some of the restrictive assumptions of the model. The assumption of stochastic independence was relaxed by the GEV model (McFadden, 1978, Ben-Akiva and Francois, 1983). The assumption of homogeneity of preferences was relaxed by models such as the random parameter logit model (Ben-Akiva and Bolduc, 1996, Bolduc *et al.*, 1996, Ben-Akiva and Bierlaire, 1999, Train 2003). The assumption of homogeneity in variance/scale was relaxed by models that include the scale function (Swait and Louviere, 1993). However, other assumptions within the RUM framework have not been fully explored.

This thesis examines three of the above assumptions in detail. It proposes ways to relax the assumptions, or evaluates methods of relaxing the assumptions of RUM, and provides empirical information for policy analysis. It consists of three studies that are expected to provide a better understanding of choice behavior by developing and/or employing extensions of the RUM framework. The first assumption to be examined is that decision makers make choices from a full, known set of alternatives. This thesis evaluates different methods of relaxing this assumption. Second, the thesis proposes a new technique to relax the compensatory preference assumption. Finally, the thesis explores structural models that allow for personal perceptions of attribute levels. This thesis has three objectives. The first is to evaluate models of choice set formation and the effect they have on preference measures and welfare estimates. This will be done in the context of recreation demand over time. The second is to model non-compensatory preference in the framework of RUM and estimate cutoff levels as a function of individual characteristics. The third is to separate subjective perceptions and objective levels of attributes and investigate factors that affect subjective perceptions using a structural mode.

1.1 Choice set formation

When facing a set of alternatives, decision makers may narrow their choice sets using some specific criteria, and make the choice within the alternatives remaining in their individual choice sets. Some alternatives may be excluded from the individual choice set if their attributes do not meet certain thresholds or levels. The process of narrowing the choice set is called choice set formation. Ignoring choice set formation processes can result in biased estimates of the utility function parameters (Swait and Ben-Akiva, 1987).

The first study of this thesis investigates alternative models of choice set formation by analyzing the responses of Albertan hunters to chronic wasting disease (CWD – a prion disease that affects deer and elk and was found in Alberta in 2005 (Government of Alberta, 2010)). Typical analysis of recreation choice data ignores the choice set formation process – potentially resulting in incorrect predictions and policy prescriptions (Peters *et al.*, 1995; Parsons and Hauber, 1998). Few researchers have modeled the choice set formation process endogenously – as an integral component of the choice process. The CWD context provides an application in which hunters may remove alternatives from their choice set when they know that the site is affected by the disease. Thus this case is an excellent situation to conduct analysis of choice set formation as a methodological assessment and as a contribution to the policy process of the management of CWD. This study examines whether and how attributes, specifically CWD, can affect evaluation and choice set formation over time using different choice set formation models.

This study evaluates the two methods of modeling choice set formation, particularly the Independent Availability Logit model (Swait, 1984), which is the fully endogenous choice set formation model, and the availability function approach (Cascetta and Papola, 2001) that approximates choice set formation. The study separates the responses to CWD risk and new information on CWD into the effect on the choice set and the effect on preferences. By using data from hunters' site choices over a two year period, the study provides a richer understanding of choice behavior, including choice set formation, over time. The scale function, which relaxes the assumption of homogeneous variance, is also incorporated. The study also makes an empirical contribution by providing measures of the welfare impact of CWD over groups of hunters and over time.

1.2 Non-compensatory preferences

The fact that some alternatives may not be considered if their attributes do not satisfy some requirements can be viewed as a choice set formation process, but it can also be viewed as a form of non-compensatory preference. In the case of non-compensatory preferences a change in one attribute may not be compensated for by a change in another attribute. As a result, alternatives that do not satisfy certain requirements of the decision makers will never be chosen, even if they are in the choice set. Choosing the utility maximizing alternative from the set of alternatives in choice set formation model is essentially the same as choosing the optimal one that satisfies the requirements in non-compensatory models (Swait, 2001).

Typical applications of the RUM assume a linear utility function. This implies perfect compensation or "tradeoffs" between attributes, which has been criticized as it may not adequately capture preferences. A non-compensatory framework may be better, but it requires that a certain level of an attribute must be satisfied in order for an alternative to be considered – this level is referred to as a "cutoff". Alternatives that violate cutoffs may be penalized in terms of utility, or eliminated from the choice set if the penalty is large enough.

Gensch and Svetska (1984), Elrod *et al*. (2004) and Martinez *et al*. (2009) proposed various methods to estimate cutoffs. However, these methods estimate aggregate cutoffs and thus do not allow for different cutoffs points for different individuals. In other research that involves cutoffs, the cutoffs are usually elicited directly from the respondents, and are assumed to be exogenous. However this information is not always available and the elicitation may introduce other econometric difficulties in the model. Self-reported cutoffs have been shown to be unreliable because decision makers may be willing to change or violate their cutoffs when evaluating a particular alternative (Swait, 2001, Huber and Klein, 1991, Klein and Bither, 1987). Therefore, there is a need for a model that can test for the existence of cutoffs as well as estimate the cutoff levels without prior information about the cutoffs.

The second study develops a new method that modifies the standard MNL model to estimate cutoff levels and correlate cutoffs with individual characteristics. The model is tested with synthetic data. The model is then applied to choices by Albertans of different policy strategies for conserving woodland caribou, which is listed as a "Threatened" species (COSEWIC, 2002, ASRD and ACA, 2010). By estimating cutoffs in this case the study can identify the preferences for, and economic value of, conservation programs, and assess the extent to which there are thresholds or cutoffs in these preferences. Estimated cutoffs are also compared to elicited cutoffs. This paper also makes an empirical contribution by providing estimates of the willingness to pay for threatened species conservation and information on thresholds or cutoffs over the population sampled.

1.3 Subjective perception of attributes

When considering alternatives that involve risk attributes, decision makers may eliminate alternatives that may be considered "too risky", which is the case for choice set formation processes. However, the decision makers may not think about the risk data in the same way as they are presented by researchers. When presenting decision makers with the choice set, researchers usually present the set of attributes of each alternative and assume that the decision makers will make choices based on the information provided (objective values). This ignores the possibility of subjective perception of attributes. As a result, using objective values to analyze the choice behavior may be misleading.

The issue of subjective perception of attributes has been discussed in the environmental valuation literature. Adamowicz *et al*. (1997) found that the model estimated using perceived values of attributes (obtained directly from respondents) outperforms the model that uses objective attribute values. The issue may be even more important in the elicitation of risk preferences given that individuals often have difficulties processing risks and probabilities of outcomes.

The third study examines perceptions versus objective measures of risk. Analysis of risk aversion usually employs an expected utility model, which does not account for the possibility that subjects may perceive probabilities or hold subjective beliefs about probabilities. Ignoring the fact that subjects may subjectively weight probabilities may result in biased estimates of the risk aversion coefficient of the utility function.

This study analyzes data from Harrison *et al*. (2005). Each alternative in this study involves different outcomes with different objectively described probabilities. A structural model is developed which effectively allows subjects to apply weights to objective probabilities in order to form subjectively weighted probabilities, and make choices based on these weighted probabilities. A RUM with a scale function, nonlinear utility and weighting function together with random parameters is applied to analyze the choice under uncertainty. This study employs a structural model to separate subjective perceptions and objective levels of attributes in choice, and to investigate factors that affect subjective perceptions.

In summary, this thesis examines three areas of individual choice behavior. Each study either evaluates or proposes methods to relax assumptions about choice behavior or preferences. The first study finds that choice set formation affects welfare measures, and this effect may change over time or by the provision of information. This highlights the importance of including choice set formation processes in analyses that involve risk and wildlife, and probably other cases as well. The study also finds that the approximation of choice set formation (Cascetta and Papola, 2001) may not adequately reflect choice set formation and capture such effects. The model that captures non-compensatory preferences developed in the second study is found to be able to recover the true parameters when applied to synthetic data. This model shows that such cutoff information is important to include in empirical analysis and that the results differ from models that use self-reported cutoffs. In the third study, it is found that perceptions of attributes may play a significant role in the process of choice decision, and particularly for the research problem examined in this study, it may considerably affect the measurement of risk aversion.

The next three chapters present the three studies. Chapter 2 examines the choice set formation models using the responses of Albertan hunters to chronic wasting disease. Chapter 3 proposes a model that estimates cutoffs endogenously and then applies the model to data from a survey in Alberta about woodland caribou conservation. Chapter 4 explores structural models that allow for subjective perception of attributes to the analysis of choice under uncertainty. Chapter 5 provides some general conclusions.

REFERENCES

Adamowicz, W., J. Swait, P. Boxall, J. Louviere and M. Williams. 1997. Perceptions Versus Objective Measures of Environmental Quality in Combined Revealed and Stated Preference Models of Environmental Valuation. *Journal of Environmental Economics and Management* 32: 65–84.

Alberta Sustainable Resource Development and Alberta Conservation Association. 2010. Status of the Woodland Caribou (Rangifer tarandus caribou) in Alberta: Update 2010. *Alberta Sustainable Resource Development. Wildlife Status Report No. 30 (Update 2010)*. Edmonton, Alberta.

Ben-Akiva, M. and B. Francois. 1983. μ-Homogeneous generalized extreme value model. Working paper, Department of Civil Engineering, MIT, Cambridge.

Ben-Akiva, M. and D. Bolduc. 1996. Multinomial probit with a logit kernel and a general parametric specification of the covariance structure. *Paper presented at the 3rd Invitational Choice Symposium, Columbia University*.

Ben-Akiva, M. and M. Bierlaire. 1999. Discrete choice methods and their applications to short-term travel decisions, in R. Hall (ed.), *Handbook of Transportation Science,* Kluwer, pp. 5-34.

Bockstael, N.E. and K.E. McConnell. 2007. *Environmental and Resource Valuation with Revealed Preferences*. Dordrecht, The Netherlands: Springer.

Bolduc, D., B. Fortin and M. Fournier. (1996). The effect of incentive policies on the practice location of doctors: A multinomial probit analysis, *Journal of Labor Economics* 14 (4): 703-732.

Cascetta, E., A. Papola, 2001. Random utility models with implicit availability/perception of choice alternatives for the simulation of travel demand. *Transportation Research Part C* 9 (4): 249–263.

COSEWIC. 2002. COSEWIC assessment and update status report on the woodland caribou *Rangifer tarandus caribou* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa.

Elrod, T., R.D. Johnson and J. White. 2004. A new integrated model of noncompensatory and compensatory decision strategies. *Organizational Behavior and Human Decision Processes* 95: 1-19.

Gensch, D.H. and J.A. Svetska. 1984. A Maximum Likelihood Hierarchical Disaggregate Model for Predicting Choices of Individuals. *Journal of Mathematical Psychology* 28: 160-178.

Government of Alberta. 2010. Sustainable Resources Development website. *Chronic Wasting Disease*. http://www.srd.alberta.ca/BioDiversityStewardship/WildlifeDiseases/ChronicWastingDisease/Default.aspx Accessed 8 February 2011.

Grafton, Q., W.L. Adamowicz, D. Dupont, H. Nelson, R. Hill and S. Renzetti. 2003. *The Economics of the Environment and Natural Resources*. Blackwell.

Harrison, G. and E.E. Rutström. 2008. Risk Aversion in the Laboratory. *Research in Experimental Economics* 12: 41-196.

Huber, J. and N. M. Klein. 1991. Adapting Cutoffs to the Choice Environment: The Effects of Attribute Correlation and Reliability. *Journal of Consumer Research* 18(3): 346-357.

Klein, N. M. and S. W. Bither. 1987. An Investigation of Utility-Directed Cutoff Selection. *Journal of Consumer Research* 14(2): 240-256.

Luce, R. D. 1959. Individual Choice Behavior: A Theoretical Analysis. New York: Wiley.

McFadden, D. 1978. Modeling the choice of residential location. *Transportation Research Record* 672: 72-77.

Manski, C.F. 1977. The Structure of Random Utility Models. *Theory and Decision* 8: 229-254.

Marschak, J. 1960. Binary-choice constraints and random utility indicators. In Mathematical Methods in the Social Sciences, edited by K. J. Arrow, S. Karlin, and P. Suppes. Stanford, California: Stanford University Press.

Martinez, F., F. Aguila and R. Hurtubia. 2009. The constrained multinomial logit: A semi-compensatory choice model. *Transportation Research Part B* 43: 365-377.

Peters, T., W. Adamowicz and P. Boxall. 1995. The Influence of choice set consideration in modelling the benefits of improved water quality. *Water Resources Research* 613: 1781-7.

Parsons, G. and A. Hauber. 1998. Spatial boundaries and Choice Set Definition in a Random utility model of Recreation Demand. Land *Economics* 74(1): 32-48.

Swait, J. 1984. Probabilistic choice set formation in transportation demand models. Unpublished Ph.D. Thesis. Department of Civil Engineering, MIT, Cambridge, MA.

Swait, J. 2001. A non-compensatory choice model incorporating attribute cutoffs. *Transportation Research Part B* 35: 903-928.

Swait, J. and J.J. Louviere. 1993. Role of the scale parameter in the estimation and comparison of multinomial logit models. *Journal of Marketing Research* 30(3): 305-314.

Swait, J. and M. Ben-Akiva. 1987. Incorporating random constraints in discrete choice models of choice set generation. *Transportation Research B* 21(2): 91-102.

Thurstone, L.L. 1927. A Law of Comparative Judgment. *Psychological Review* 4:273-286.

Train, K. 2003. Discrete Choice Methods with Simulation. New York: Cambridge University Press.

CHAPTER 2: MODELLING THE EFFECT OF RISK PERCEPTION ON PREFERENCES AND CHOICE SET FORMATION OVER TIME: RECREATIONAL HUNTING SITE CHOICE AND CHRONIC WASTING DISEASE

The economics of recreation demand was initially analyzed using the travel cost model (Hotelling 1949 and Clawson 1959), in which the demand for trips to a specific site decreases with price (travel cost). The application of random utility models (RUM) to recreation site choice allows for the analysis of the effect of attributes other than price on recreation demand (including potential health risks at sites), and to more fully examine substitution patterns between options. The site choice model was proposed by Hanemann (1978), in which every trip is considered a choice where an individual is assumed to choose the site that maximizes his utility, given the constraint of income and time.

The application of RUMs to recreation site choice allows the analysis of the response to health risks by considering this risk as a site attribute. Some researchers have examined the response of recreation demand to risk perceptions. Diana *et al*. (1993) and May and Burger (1996) examined anglers' compliance with health advisories and found most anglers ignored consumption advisories. Jakus *et al*. (1997), however, found anglers were less likely to visit a reservoir with an advisory. Jakus and Shaw (2003) proposed a two-level nested multinomial logit (MNL) model to analyze the behavior of keeping fish from sites simultaneously with site choice behavior. The probability of not keeping fish from a site is considered a proxy of hazard perception and this was found to drive anglers away from a site. Zimmer *et al*. (2012) analyzed the effect of Chronic Wasting Disease (CWD), a degenerative wasting disease that affects deer, moose and elk, on hunting site choice in Alberta using a nested MNL model and found that the prevalence of the disease as well as wildlife management disease mitigation efforts affect site choice.

One of the key components of the RUM approach is the definition of the choice set, the set from which the consumer chooses a preferred option. The choice set is often defined exogenously by the researcher, based on rules or data availability. Increasingly, however, it is being recognized that choice set formation, or endogenous choice set determination, is an important component of consumer behavior (Swait 1984, 2001a). This applies in the recreation demand case that we study, as well as in cases of transportation mode choice, food product choice, housing choice, and other areas where random utility models are employed.

To the best of our knowledge, none of the previous research examining health risks and recreation choice analyze response to risk in a two-stage decision process to account for the process of choice set formation. If there are a large number of possible sites, decision makers may narrow their choice sets using some specific criteria, and then make a choice within those sites in their individual choice sets. Mis-specification of individual choice sets, for example including alternatives that are not actually considered by the respondents or not including those considered, might result in biased estimates of the utility function and welfare measures (see, for example, Hicks and

Strand, 2000). Failing to include relevant alternatives or including irrelevant alternatives may introduce bias to the estimated parameters and welfare measures. This is because the modeled probability of choosing an alternative j depends on the choice set, and thus the log-likelihood function also depends on the choice set.

Several attempts have been made to deal with the issue of choice set formation in the RUM. Peters, Adamowicz and Boxall (1995) asked respondents to specify the alternatives to be considered before making final decisions. Choice set formation has also been modeled endogenously. Haab and Hicks (1997) Swait (1984), Swait and Ben-Akiva (1986, 1987a,b), Roberts and Lattin (1991), Andrews and Srinivasan (1995), Ben-Akiva and Boccara (1995), Chiang *et al*. (1999) and von Haefen (2008) have explicitly modeled choice set formation based on the two-stage choice process as formulated by Manski (1977). Swait (2001a) developed a model that does not consider choice set generation as a separate construct, but another expression of utility.

The explicit modeling of choice set formation is challenging when there are large choice sets, and models approximating the choice set formation process have been developed. Cascetta and Papola (2001) introduced the implicit availability perception function as an extension of the standard MNL model to allow decision makers to have an individual degree to which an alternative is considered for final decision (see also Kuriyama *et al*. 2003). The model is extended by Martinez *et al*. (2009). While this approach is an approximation, it does provide a tractable method for incorporating choice set formation into RUM models that have many alternatives.

In this paper we examine consumer (hunter) response to potential health risks that arise from the prevalence and spread of Chronic Wasting Disease. Chronic Wasting Disease (CWD) is a prion disease that affects elk, deer and moose and was recently found in Alberta. CWD is essentially the cervid species form of “mad cow disease” or Bovine Spongiform Encephalopathy (BSE). However, unlike BSE, there is no known link between the consumption of CWD affected meat and human health. Nevertheless, hunters are advised to have animals from CWD affected areas tested and are advised against consumption of meat from CWD infected animals (Government of Alberta, 2010). The Government of Alberta has implemented several activities to prevent the spread of CWD which confounds the impact of the disease (see Zimmer *et al*. 2012). In our analysis we attempt to untangle these components. It could be the case that hunters may initially ignore the potential risk of CWD and (dis)like CWD prevention activities, but may change their preferences and behaviors later on through learning. Our data include two years of hunter activity, thus offering a chance to examine changing behavior over time. Our analysis aims to measure the economic impact of CWD on recreational hunting, and contribute to the analysis of behaviors in the presence of risk.

This study applies the availability models – models that account for the availability of sites in the choice set – to analyze the responses of hunters to potential health risk in both stages of choice set formation and site choice evaluation; specifically the responses of hunters to CWD prevalence in Alberta. Two availability models are employed: the Cascetta and Papola (2001) approach and the fully specified Independent Availability Model (IAL) that accounts for choice set formation. We also compare the results from the two models.

It is also possible that individual choice sets, and evaluation of alternatives, may change over time with changes in information. The psychology literature suggests that people are more likely to repeat an action if it produced favourable outcomes (the law of effect), that the learning effect is initially higher (the power law of practice), and that recent experience has higher impact (recency) (Erev and Roth 1998, Nicolaisen *et al*. 2001, Bunn and Oliveira 2001). In general, people will adjust their behaviors in order to maximize their utility along with the process of learning. The learning process may affect hunting site choice in two stages: choice set formation and site evaluation. On choice set formation, learning about the potential risk of CWD may make hunting sites with high occurrence of CWD less likely to be included in the choice set. In the utility function, the learning process may also make sites with high CWD occurrence less desirable over time.

This study uses a dataset that includes two years of stated and revealed preference data of site choices of Albertan hunters. The data allow for analysis of the effect of learning on choice set formation and preferences over the two time periods. The study analyzes whether and how CWD affects site evaluation and choice set formation over time using the two models. In so doing, we are also able to compares the two models.

An availability function is introduced to the standard RUM to analyze the process of choice set formation. Including CWD and time period variables into the availability function can help investigate the CWD effects on choice set formation, which is assumed to be a result of the learning process. Changes in hunting site preference can be investigated by examining the utility function. The marginal (dis)utility of the attribute

CWD could change over time as the disease spreads and management to arrest its spread and prevalence are implemented. In addition, scale parameters are also estimated for the SP and RP components of the data set each year to account for differences in error variances over time and between stated and revealed preference data sources (Swait and Louviere, 1993). This study contributes to the broader recreation demand literature by incorporating choice set formation, scale and temporal impacts into a random utility model of recreation demand. We also assess the importance, in terms of statistical performance and welfare impacts, of the inclusion of these aspects of choice.

2.1 LITERATURE REVIEW

As mentioned above, there are several studies that examine recreation site choices in response to health risks. Jakus *et al*. (1997) analyzed the effects of sportfish consumption advisories on fishing site choice in Tennessee and found that anglers considered advisories in making fishing site choice, and that advisories posted to a reservoir tend to drive anglers away from that reservoir. Jakus and Shaw (2003) introduced a perceived hazard function into the site choice model. This perceived hazard function estimates the probability of keeping fish from a site. Because keeping fish caught is assumed to be for eating, it could be considered a risk perception function. The perceived hazard function is then introduced to the site choice model as an attribute. Jakus and Shaw did not find a significant effect of advisory awareness on the probability of keeping fish, but found that higher risk perceptions for a site drive anglers away from the site.

Zimmer *et al*. (2012) analyzed the hunting site choices of Albertan hunters, focusing on responses to CWD risk and prevention activities. Zimmer found that hunters were less likely to visit a site with higher CWD prevalence. In addition, one CWD management activity (culling) was found to have a negative effect on site demand, while another one (extra tags – licenses allowing additional deer harvest) was found to have a positive effect. Data from Zimmer *et al*. are part of the data used in this chapter.

Some alternatives may not be in a choice set of an individual for several reasons. For example, the individual may not know about some recreational sites, or rule out some sites using some individual-specific criteria. Although ignoring the choice set formation process might result in biases (see Haab and Hicks 1999 for a review), choice set formation was not modeled explicitly in the above mentioned risk perception research. In Jakus *et al*. (1997), distance was the main factor used to identify the choice sets. A reservoir located far away from an angler's origin was eliminated from the choice set of anglers from that county, unless at least one angler in the county visited it. Jakus and Shaw (2003) did not discuss choice set formation, and all anglers faced a choice set of 12 major reservoirs. Zimmer *et al*. (2012) analyzed the choice model with a two-level nested random parameter logit model, but this does not capture the choice set generation processes.

2.1.1 Choice set definition

Researchers have used survey responses or exogenous information to define choice sets. Peters, Adamowicz and Boxall (1995) estimated two models, one with all sites known to researchers as the choice set and another with choice sets that only include sites actually visited or known to individuals. Their results show that using all available sites as a choice set might result in biased estimates of preferences and welfare. Parsons and Hauber (1998) analyzed day-trip fishing demand in Maine and defined choice sets using spatial boundaries. Choice sets available to an individual included 12 randomly drawn sites within the range of 0.8 hours from the individual's home. They also vary the boundary from 0.8 up to 4 hours by 0.2 hour increments, and found that estimates change when the boundary changes. This implies that choice set mis-specification may result in biased estimates of the utility function parameters. Hicks and Strand (2000) analyzed the effect of water quality on recreational beach use in Maryland with choice models. Models with three different choice sets were estimated: all sites, those within a specified distance and those familiar to the respondents (identified using survey techniques). They found that parameters and welfare measures are sensitive to choice set definition. Jones and Lupi (1999) examined the demand for recreational fishing activities in the Great Lakes using a nested logit model. They found that models that omit relevant alternatives in the choice sets will result in biased utility functions and incorrect welfare measures.

Aside from identifying the choice sets using survey responses or certain rules such as distance or familiarity, choice set formation can also be modeled in different ways. Swait (1984), Swait and Ben-Akiva (1987a) and Ben-Akiva and Boccara (1995) developed a formal two-stage model where the first stage consists of a choice set generation process, which considers all possible subsets from a given set of all alternatives. Haab and Hicks (1997) developed a similar model presented in the section 2.1.2. Cascetta and Papola (2001) proposed a RUM with an implicit availability perception function, which allows us to estimate the degree to which an alternative is available for consideration of an individual. The next section briefly introduces these two models.

2.1.2 Explicit modeling of choice set generation

Models with explicit choice set generation process are based on the two-stage decision process of Manski (1977), in which the probability of choosing alternative j is

$$p_j = \sum_{C_k \subseteq C_m} P(j \mid C_k) Q(C_k) \qquad (2.1)$$

where $Q(C_k)$ is the probability that C_k is the true choice set, $P(j \mid C_k)$ is the probability of choosing alternative j, conditional on the given choice set C_k, C_k is the choice set in C_m, which is the set of subsets of the universal set M. Note that k is an index for a choice set being in C_m and m is an index for all possible subsets of the universal set M.

Well-known models constructed based on Manski's approach includes the Independent Availability Logit (IAL) Model (Swait 1984, Swait and Ben-Akiva 1987a and Ben-Akiva and Boccara 1995), the GenL model (Swait 2001a), and the endogenous choice set model of Haab and Hicks (1997).

In the IAL model, the probability that C_k is the true choice set is given by

$$Q(C_k) = \frac{\prod_{j \in C_k} A_j \prod_{l \notin C_k} (1 - A_l)}{1 - \prod_{h \in C_m} (1 - A_h)} \qquad (2.2)$$

where A_j is the probability of alternative j in choice set C_k, which can be modeled as a binary logit model $A_j = \frac{1}{1+e^{-\gamma Z_{ij}}}$. In this model $P\left(j \mid C_k\right)$, which is the probability of choosing alternative j conditional on the choice set C_k is defined by a standard MNL model. The IAL model assumes the probability of being considered for each alternative is independent of that of other alternatives.

Swait (2001a) proposes the GenL model that models choice set generation as another expression of preferences, not a separate construct. The probability of choice set C_k being considered is defined as a monotonic transformation of the expected utility of all alternatives in the choice set

$$Q\left(C_k\right) = \frac{e^{\mu I_k}}{\sum_{r=1}^{K} e^{\mu I_r}} \text{ where } I_k = \frac{1}{\mu_k} \ln\left(\sum_{j \in C_k} e^{\mu_k V_j}\right) \qquad k = 1, \ldots, K$$

(2.3)

where μ is the scale parameter for the choice set formation stage, I_k is the inclusive value of choice set C_k, and μ_k is the scale parameter. Similar to IAL, in this model $P\left(j \mid C_k\right)$ is defined by a standard MNL model.

Haab and Hicks' (1997) applies a variation of Manski's framework to construct an endogenous choice set model with the probability of choosing alternative j defined as

$$p_j = \sum_{C_k \subseteq C_m} P\left(j \mid j \in C_k\right) P\left(j \in C_k\right) \qquad (2.4)$$

where $P\left(j \mid j \in C_k\right)$ is the probability of choosing alternative j conditional on the fact that j is in the choice set, $P\left(j \in C_k\right)$ is the probability of alternative j being in the choice set C_k. Considering all possible subsets from the universal set of J alternatives, the probability is

$$p_j = \sum_{k=1}^{2^J-1}\left[P\left(j \mid j \in C_k\right)\prod_{j\in C_k} P_j \prod_{j\notin C_k}\left(1-P_j\right)\right] \qquad (2.5)$$

In this model, $P\left(j \mid j \in C_k\right)$ is defined as in a standard MNL model, while the probability of alternative j being in the choice set C_k is defined as a function of individual specific or alternative specific variables.

Note that in all the three models presented above, the likelihood function is the standard one $L = \prod_{i=1}^{N}\left(p_{ij}\right)^{y_i}\left(1-p_{ij}\right)^{1-y_i}$ with p_{ij} - the probability of individual i choosing alternative j - defined by (2.5) as for Haab and Hicks' model, by (2.1) as for IAL and GenL model with $Q\left(C_k\right)$ from (2.2) for IAL model and from (2.3) for the case of GenL model.

Note that Haab and Hicks' model and the IAL model need to account for all possible choice sets C_m of the universal set M. The number of possible choice sets is $K = 2^J - 1$ which is quite large for choice problem with a large number of alternatives J. The GenL model does not require enumeration of all choice sets. However there is no obvious logical rule to limit the number of choice sets to the choice problem under consideration in this paper, which has 11 alternatives within the CWD management area. In addition, the GenL model requires the estimation of the inclusive value for each choice set. This makes GenL model not tractable for data with 11 alternatives as in our case.

In a recent development, von Haefen (2008) applied a Kuhn-Tucker demand system to model latent consideration sets. The model is attractive because it is tractable for large choice sets and can be estimated using standard econometric techniques.

Among Haab and Hicks, IAL and von Haefen models that are tractable for our data. However the von Haefen approach employs a theoretical and empirical framework that is quite different from the random utility model which is used in much of the literature and is the focus of this thesis. Therefore, we focus on the Haab and Hicks and IAL approach and do not examine the von Haefen model. We choose the IAL model to analyze the two-stage decision process.

2.1.3 Cascetta and Papola's Implicit Availability and Perception model

The models constructed above were on the basis of Manski's (1977) two-stage choice process and the number of possible choice sets is very large for large scale choice problems. If the number of alternatives is 11 (as in our case), the number of possible choice sets is 2,047. This makes those models challenging to apply for large choice problems. Several alternative models that approximate the choice set generation process have been proposed (Bierlaire *et al*. 2010), one of which is the implicit availability and perception model by Cascetta and Papola (2001) (we refer to this as the

CP model from now on). This model is expanded on by Martinez *et al*. (2009) (the constrained multinomial logit model - CMNL).

The CP model does not consider all possible choice sets, but rather estimates the degree to which an alternative is considered by decision makers. The availability of alternative j to individual i is modelled by a continuous variable in the domain of $[0,1]$. The probability of choosing alternative j becomes

$$p_{ij} = \frac{A_{ij} e^{\mu V_{ij}}}{\sum_{k=1}^{J} A_{ik} e^{\mu V_{ik}}} \qquad \text{or} \qquad p_{ij} = \frac{e^{\mu V_{ij} + \ln A_{ij}}}{\sum_{k=1}^{J} e^{\mu V_{ik} + \ln A_{ik}}} \tag{2.6}$$

If the availability factor A_{ij} is equal to 1, the utility model reduces to the standard MNL model. If A_{ij} is less than 1, the alternative j is less likely to be considered. To satisfy $0 \le A_{ij} \le 1$, the availability function can be defined as

$$A_{ij} = \frac{1}{1+e^{-\alpha Z}} \tag{2.7}$$

where Z is a set of variables that affect choice set formation and α a vector of corresponding parameters. Note that the formulation above is slightly different from Cascetta and Papola (2001) since the availability factor $\ln A_{ij}$ is not multiplied by the scale factor. For the model in equation (2.6), the function $G(y) = \sum_{j \in C} A_j y_j^{\mu}$ is a valid GEV generating function. Also note that the availability factor A_{ij} can be explained as a penalty to the utility function. The model in (2.6) is equivalent to a MNL model with the utility function

$$U_{ij} = V_{ij} + \frac{1}{\mu} \ln A_{ij} + \varepsilon_{ij} \qquad (2.8)$$

and $\frac{1}{\mu} \ln A_{ij}$ can be considered a penalty since it is negative. Martinez *et al*. (2009) expanded this model to model cutoffs or non-compensatory preferences in a random utility framework.

The CP model does not properly model two-stage decision process. It does not explicitly model the choice set formation by analyzing the probability of each choice set being considered. Rather, it directly models the probability of being considered of each alternative. However, it is attractive because of its ease of estimation. We choose this model to compare with the IAL model because if the CP model is a good approximation of the IAL model, then CP model is more desirable because the IAL model is much more complex, although it is still tractable for our case study.

2.1.4 Applications

Some researchers have applied the explicit approaches of modelling choice set formation, but these are limited to cases with small choice sets. Swait (1984) applied the IAL model to transportation mode choice with four alternatives. Haab and Hicks (1997) applied their model to two cases. The first is with 5 alternatives, the second is 12 alternatives. For the second example, the number of possible choice sets is obviously large. However Haab and Hicks eliminate 6 among the 12 alternatives using a set of logical rules. This obviously helps reduce computational complexity.

Bovy (2009) provides a review of choice set generation modelling approaches, specifically applied to route choice in transportation networks. Başar and Bhat (2004) applied the IAL model to analyze choice set generation, applying it to an airport choice problem with three airports. Swait and Erdem (2007) applied the IAL model to investigate the brand effect on choice and choice set formation with two case studies, one with 6 alternatives and one with up to 10 alternatives. Hicks and Schnier (2010) analyze fishing zone choice with Manski's two-stage model, but group zones to macro-regions to reduce the complexity of the choice set generation stage, while retaining micro-regions at the choice stage. This approach is useful but may not be applicable to all choice problems.

Bierlaire *et al*. (2010) compared the two approaches (CMNL and Manski's) using synthetic data (with a 3 alternative choice problem) and found that while Manski's model is unbiased, the CMNL is sometimes a poor approximation. The Martinez *et al*. (2009) model is also discussed by Bierlaire *et al*. (2010) as an alternative formulation of the problem.

2.2 DATA

Data for this study come from the survey discussed by Zimmer (2009) and come from two different years. The first hunting season trip information comes from 2007 and is used in the study by Zimmer *et al*. (2012). The second year of trip data (2009) were collected from a subset of the respondents who provided information in the first year. Thus, the information from the two periods arises from the same sample of individuals - which is relatively rare in the recreation demand literature. The dataset consists of demographics and hunting site (WMU) choice of Albertan hunters and the four attributes described above for the two years. The hunting sites include those within

CWD surveillance zones including WMUs 148, 150, 151, 162, 163, 200, 234, 236, 256 and 500. Those outside of CWD surveillance zones are coded as 999.

WMUs were originally created based on geographic and ecological variations by Alberta Sustainable Resource Development (SRD) to manage wildlife populations. Culling and extra tags are part of the strategy by SRD to combat the threat of CWD spread that might affect hunting activities, which generate annual revenue of $71 million (Federal-Provincial-Territorial Task Force 2000) in Alberta. Culling was undertaken to reduce the deer herds in areas where infected animals were identified. Extra tags, which allow for additional deer harvest, were provided as an incentive to hunters who submit their harvested deer heads for testing and to reduce deer populations.

The data set has both revealed preference (RP) and stated preference (SP) choices in two hunting seasons, with a total of 4,362 observations or choices. Table 2.1 describes the structure of the data. Hunters were sampled by postal code from the hunting license database. Hunters were contacted by telephone and invited to take the survey online. A total of 84 hunter surveys were usable in 2007 and 37 in 2009.[1] Each survey first asked hunters how many hunting trips they made in 2007 and locations (WMUs) for the RP data. Then for the SP part, the survey asked again where and how many trips they would

[1] We note that the sample sizes employed are small, hence we make no claims about the ability of our study to predict the behavior of all Albertan deer hunters who may be affected by CWD. Rather we employ this data as a convenience sample to examine the usefulness of our empirical approaches.

take in new (hypothetical) situations where CWD occurrence and the presence of extra tags and culling program were altered such that they are not correlated as they were in RP data. For a complete experimental design, see Zimmer (2009). See Appendix 1 for the 2009 survey questionnaire.

Table 2.1: Data structure – number of choices

	Year 1 (2007): 84 hunters	Year 2 (2009): 37 hunters	Total
Revealed preference	748	308	1,056
Stated preference	2,532	774	3,306
Total	3,280	1,082	4,362

2.3 EMPIRICAL MODEL

Our empirical analysis examines choices from 11 alternative hunting sites over two time periods. Because of potential confounding between CWD and management programs used to combat CWD (culling and allocation of additional hunting tags) revealed preference data alone cannot identify the effect of CWD on site choice. Therefore, a set of stated preference questions about site choice was included in the survey of hunters. The stated preference data are included with the revealed preference data. Using these data we model site choice, availability (choice set formation) and scale. The effect of time on preferences, availability and scale is examined using dummy variable interactions. For the problem under consideration, the CWD attribute, and its interaction with a time dummy variable can be included in the utility function and the availability function. In this case, if learning over time heightens the perception of risk, the interaction term is expected to have a negative impact on the availability of the alternative, implying that in the second year, hunters are less likely to include sites with higher occurrence of CWD in their choice sets, and also have a higher marginal disutility of CWD.

The scale function $\mu_i = \mu(z)$, which is inversely related to the variance (Ben-Akiva and Lerman 1985), is also estimated, where z is a set of relevant variables, including a time dummy and a dummy variable indicating whether the data are stated or revealed. The detailed model is described below. This formulation allows for time elements and data types to affect the variance of the error component.

2.3.1.1 Attributes and variables

The attribute cwd indicates the prevalence of CWD in affected deer populations in terms of the percentage of animals infected in the population of deer in a WMU and has four levels: none (0), low (1 to 5), medium (6 to 10), and high (>10). Midpoints are used, so the levels are 0, 2.5, 7.5 and 12.5 percent. The travel cost tc is calculated using travel time, distance and hunters' income (see Zimmer *et al*. 2012)

$$tc = \text{distance} \times 2 \times 0.3 + \left(0.25 \times \frac{\text{total income}}{2080}\right) \times \frac{\text{distance} \times 2}{95}$$

The first component is the driving expense for the round trip ($\text{distance} \times 2$) at a cost of \$0.3/km. The second component is the opportunity cost of time, calculated by multiplying the hourly opportunity cost of time ($\left(0.25 \times \frac{\text{total income}}{2080}\right)$, or 25% of total income divided by the average yearly working hours) and travel time of the round trip at a speed of 95 km/h.

The attribute $tags$ indicates the presence of an extra hunting tag program, so is a dummy variable. Similarly the attribute $cull$ is a dummy indicating the presence of a culling program. Table 2.2 summarizes the attributes and levels.

Table 2.2: Attributes and levels

Attributes	Description	Levels
tc	Travel cost, computed from distance & income	Continuous, mean=238, min=0, max=648
cwd	CWD level – percent of deer population infected with CWD	None 0, low 1-5, medium 6-10, high >10. Midpoints are used 0, 2.5, 7.5 and 12.5.
$tags$	Presence of an extra tags program	0, 1
$cull$	Presence of culling	0, 1

Several individual characteristics are used for interacting with attributes:

- $yr2$: a dummy indicating the choice is in hunting season 1 (=0) or 2 (=1).
- $urban$: a dummy indicating whether the hunter is living in an urban area (= 1) or not (= 0).
- $yrshunt$: number of years the hunter has been hunting.
- age : age of the hunter of the time of survey.

2.3.1.2 Utility function

A utility function is assumed to have alternative specific constants (ASCs), attributes and selected interactions:

- ASC for hunting sites, which are Wildlife Management Units (WMUs) including those in the CWD surveillance zones j = 148, 150, 151, 162, 163, 200, 234, 236, 256, 500, and all those outside of the zones, coded as 999. The ASCs are assumed to capture all unobserved attributes relevant to the alternatives (Murdock, 2006).

- Attributes: cwd , $tags$, $cull$, tc
- Interactions: $cwd \times yr2$ (to test for the change in the effect of CWD risk perception on preferences), $tc \times urban$ (to allow for the difference in sensitivity to travel cost between rural and urban hunters), $tags \times urban$ (to allow for a difference in response to the extra tags program between urban and rural hunters), $cwd \times urban$ (to test whether urban hunters are more sensitive to CWD than rural hunters) and $cull \times yrshunt$ (to test whether more experienced hunters are more sensitive to culling program).

The utility function is defined as

$$V_{ij} = ASC_j + \beta X_{ij} \qquad \text{for } j \neq 999$$

$$V_{ij} = ASC_j \qquad \text{for } j = 999$$

where X_{ij} includes all attributes and interactions listed above and ASC_{500} is fixed at 0. WMU 999 including all sites outside of the CWD surveillance zones does not have any management program nor any CWD prevalence. This region includes many zones such that modeling each as a site is not feasible. As a result, we treat them as a single identical site. In addition, because WMU 999 includes many sites at difference distances, travel costs to this WMU are quite variable and including travel cost in the utility function of this site is not desirable as the cost data would be pooled with other unobserved information. Therefore, the utility of WMU 999 is modeled only as an ASC. This is a limitation, but the information required to model alternatives outside the region in a more complete fashion was unavailable.

2.3.1.3 *Availability function*

The availability function is $A_{ij} = \frac{1}{1+e^{-\alpha Z_{ij}}}$ where Z includes a constant, cwd, $cwd \times yr2$ (interaction of cwd and $yr2$, to test for the difference in effect of cwd between two years), and $cwd \times urban$. We apply this specification for the CP models as well as the Independent Availability Logit model.

In this paper the effect of CWD is investigated by including CWD variables in the availability and utility functions. It is challenging to identify whether the effect of CWD is on availability or utility, or both. We try to do this by comparing different model specifications. For CPA and IAL models, we run each with two specifications, one with CWD related variables in availability only, one with those variables in both availability and utility functions.

2.3.1.4 *Scale function*

The scale parameter for a data set cannot be identified, but the ratio of the scale parameter of one data set relative to another can be identified (Swait and Louviere 1993). This can be implemented by fixing the scale parameter of one set or group to unity and estimating the others.

Because the data include SP and RP data for two years, it can be considered to have four sets or groups. Because $yr2$ and sp (1 if stated preference data, 0 otherwise) are both dummies, there will be four values of scale parameter. So the scale parameter is estimated for four groups: Group 1 ($yr2$ =0 and sp =0) has scale parameter μ_1, Group 2

($yr2$ =1 and sp =0) μ_2, Group 3 ($yr2$ = 0 and sp = 1) μ_3 and Group 4 ($yr2$ =1 and sp =1) μ_4. Fixing the scale parameter of Group 1 at 1, the scale function is $\mu_g = e^{\gamma_1 yr2 + \gamma_2 sp + \gamma_3 sp \times yr2}$.

In estimation, the scale function together with a utility and availability function make the model highly nonlinear. The models are estimated using BIOGEME (Bierlaire, 2003) and MATLAB. Likelihood ratio tests are applied to test for statistical significance of coefficients of utility and the availability function as well as the scale function.

2.4 RESULTS

Results of six models are presented in Table 2.3. The first two models are basic MNL models. Model MNL1 is the basic model with a utility function only. Model MNL2 adds the scale function. The next two models are Cascetta and Papola Availability (CPA) models, one with CWD-related variables in availability function only, and one with those variables in both availability and utility function. The last two models are the IAL models, again one with CWD-related variables in availability function only, one with those in both functions. Note that all the models involve pooled SP and RP data for the two years, and in CPA and IAL models, scale functions are always included. We first discuss the MNL and CPA models and compare these to the IAL model later in this section. We then analyze and compare the effects of CWD of models among models. Finally we compare the welfare measures of MNL, CPA and IAL models.

In all cases, the scale function significantly improves log-likelihood value. The likelihood ratio tests reject the null hypothesis that all coefficients of the scale functions are equal to zero (the scale factors are identical for all data sets) for all models. Therefore, we include the scale function in all CPA and IAL models[2].

In the scale function, in MNL and IAL models, all variables are significant. The scale factor is smaller in year 2 data and in SP data, indicating that the variance is higher in these two data types. In model CPA2, only sp is significant, implying that the scale factor is smaller for SP data, but not for the second year data. This means SP data has higher variance. However the interaction $sp \times yr2$ is significant, implying that the variance of SP data is even higher in year 2.

2.4.1 MNL and CPA models

Log-likelihood values further improve when accounting for choice set formation. From model MNL2 to CPA1, CWD-related variables are moved from utility function to availability function and it can be observed that the log-likelihood value shows a little improvement. Testing model CPA2 against model MNL2, a likelihood ratio test again rejects the null hypothesis that the availability factor is unity with p-value less than 0.001. As a result, the full model with scale and availability functions appears to be a better fit than the basic MNL model.

Most variables in the utility functions of MNL models have expected signs. Coefficients on travel costs are negative as expected. The coefficient $tc \times urban$ is positive, indicating that urban hunters are less sensitive to travel costs. Coefficient of travel cost is larger (in absolute value) in models with scale and availability function, implying that

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[2] For the case of model MNL2 against model MNL1, we observe a p-value less than 0.001.

the effects of travel cost are underestimated if the scale factor and choice set formation are ignored.

In the MNL models, $tags$ has a positive coefficient while $tags \times urban$ have negative coefficients. This means hunters are motivated by the extra tags program, but urban hunters are less motivated. The culling program drives hunters away from the sites. The parameters of $cull \times yrshunt$ are positive, indicating that more experienced hunters are less likely to dislike culling programs.

CWD prevalence has different effects on site choice formation and site choice evaluation. In the utility function, its effect varies across models. The MNL models indicate that hunters prefer sites with CWD in year 1, but dislike them in year 2. In addition, urban hunters appear to dislike site with CWD. The coefficient of $cwd \times urban$ is high enough to offset the positive coefficient of CWD such that urban hunters dislike CWD in both years. Model CPA2, however, shows that hunters dislike CWD in both years, but urban hunters appear to like sites with CWD. This is because the negative effect of $cwd \times urban$ on choice is captured by the availability function.

Table 2.3: Estimation Results: MNL, CPA and IAL Models of Site Choice

Model	MNL1		MNL2		CPA1		CPA2		IAL1		IAL2	
Log-likelihood	-7,583.41		-7,500.26		-7,472.54		-7,429.78		-7,383.03		-7,372.73	
Rho-square	0.275		0.283		0.286		0.290		0.294		0.295	
Run time [(a)]					0.7		1.3		220		983	
SCALE FUNCTION												
SP			-0.518†	(0.043)	-0.445†	(0.035)	-0.445†	(0.101)	-1.409†	(0.402)	-1.252†	(0.046)
Year 2			-0.303†	(0.070)	-0.197†	(0.047)	***0.035***	***(0.055)***	-1.05ϒ	(0.448)	-0.834†	(0.117)
Year2 x SP			0.177ϒ	(0.083)	***0.087***	***(0.058)***	-0.166ϒ	(0.09)	0.917†	(0.166)	0.76†	(0.087)
AVAILABILITY FUNCTION												
Constant					-0.158ϒ	(0.072)	-3.115†	(0.384)	-0.166	(0.209)	-0.157†	(0.053)
CWD					4.814†	(0.459)	0.975†	(0.07)	1.64†	(0.673)	1.604†	(0.079)
CWD x YR2					-0.05	(0.046)	0.127	(0.124)	-0.037	(0.135)	0.018	(0.045)
CWD x URBAN					-4.834†	(0.465)	-1.223†	(0.213)	-1.635ϒ	(0.687)	-1.653†	(0.082)
UTILITY FUNCTION												
CWD	0.04†	(0.012)	0.053†	(0.018)			-0.515†	(0.082)			-0.133†	(0.044)
CWD x year 2	-0.051†	(0.013)	-0.101†	(0.023)			-0.24†	(0.058)			-0.24†	(0.07)
CWD x urban	-0.053†	(0.013)	-0.113†	(0.022)			0.861†	(0.212)			0.315†	(0.078)
Travel cost	-15.1†	(0.442)	-23.8†	(1.09)	-22.344†	(0.555)	-22.229†	(0.628)	-55.629†	(21.508)	-49.976†	(4.059)
Tags	0.436†	(0.065)	0.706†	(0.109)	0.547†	(0.051)	0.846†	(0.162)	1.672*	(0.987)	1.666†	(0.071)
Cull	-0.444†	(0.075)	-0.867†	(0.129)	-0.831†	(0.06)	-1.19†	(0.079)	-2.723ϒ	(1.406)	-2.654†	(0.187)
Tc x urban	6.67†	(0.427)	10.6†	(0.774)	10.362†	(0.619)	10.774†	(0.604)	9.972†	(1.996)	12.623†	(1.548)
Tags x urban	-0.441†	(0.084)	-0.671†	(0.133)	-0.393†	(0.066)	-0.664†	(0.14)	-1.168*	(0.65)	-1.448†	(0.112)
Cull x hunt years	0.011†	(0.003)	0.020†	(0.004)	0.02†	(0.004)	0.022†	(0.009)	0.062	(0.076)	0.056†	(0.013)
ASC 148	0.915†	(0.172)	1.54†	(0.284)	1.519†	(0.088)	1.46†	(0.117)	2.3†	(0.649)	2.166†	(0.14)
ASC 150	1.08†	(0.172)	2.01†	(0.295)	1.624†	(0.09)	1.905†	(0.222)	2.167†	(0.477)	2.402†	(0.112)
ASC 151	1.64†	(0.158)	2.83†	(0.287)	2.402†	(0.086)	2.564†	(0.185)	4.077†	(1.069)	4.138†	(0.165)
ASC 162	0.756†	(0.163)	1.21†	(0.269)	1.275†	(0.062)	1.239†	(0.1)	2.106†	(0.727)	1.931†	(0.237)
ASC 163	1.3†	(0.155)	2.13†	(0.266)	2.189†	(0.098)	2.207†	(0.079)	5.208†	(1.982)	4.456†	(0.133)
ASC 200	1.42†	(0.148)	2.28†	(0.259)	2.278†	(0.063)	2.289†	(0.084)	5.992†	(2.269)	5.142†	(0.127)
ASC 234	1.71†	(0.152)	2.87†	(0.277)	2.287†	(0.074)	2.448†	(0.135)	5.993†	(2.421)	5.608†	(0.159)
ASC 236	1.43†	(0.149)	2.24†	(0.257)	2.25†	(0.063)	2.161†	(0.078)	7.202ϒ	(3.159)	5.964†	(0.183)
ASC 256	0.248	(0.168)	0.301	(0.277)	0.608†	(0.059)	0.539†	(0.098)	1.802*	(0.985)	1.173†	(0.051)
ASC 500	0	(fixed)	0	(fixed)	0	(fixed)	0	(fixed)	0	(fixed)	0	(fixed)
ASC 999	0.181	(0.16)	0.211	(0.262)	0.532†	(0.045)	0.601†	(0.107)	3.028*	(1.63)	2.173†	(0.125)

*Note: [(a)] in minutes, on a computer with a six-core processor at 3.47GHz. † Significant at 1% level. ϒ Significant at 5% level. * Significant at 10%. Standard errors are in parentheses.*

The effects of CWD variables in the availability function show similar pattern with those in model MNL1. Hunters are more likely to consider sites with higher CWD prevalence in year 1, less likely to consider them in year 2, and urban hunters are less likely to consider sites with higher CWD. However, the coefficient of $cwd \times yr2$ is not significant. The coefficient of $cwd \times urban$ is (negatively) large enough to offset that of CWD in both model CPA1 and CPA2, therefore urban hunters are less likely to consider sites with CWD in both years. CPA models also indicate that sites with higher CWD prevalence are more available to rural hunters. This may be based on habits and attachments to place, relative to urban hunters. It may also be that some hunters view CWD as a positive attribute as it may reduce congestion. Congestion is an endogenous component of recreation demand models and challenging to model (e.g. Timmins and Murdock, 2007) – nevertheless this may be an issue confounding the results in our case.

2.4.2 IAL models

The last two columns of Table 2.3 present the results of the IAL models that include scale effects. In terms of log-likelihood values, the IAL models are much better than corresponding CPA models as expected. In Table 2.4 below we also present the implied probabilities of choice set sizes for the sample. If the CP model and the IAL model are similar, that provides some confidence in the use of the CP model as a practical method of incorporating consideration sets.

Examining the scale function parameters, we see that the two IAL models provide qualitatively similar results to models MNL2 and CPA1. The signs are same, but the magnitudes are larger. Error variance is higher in year 2 relative to year 1 (scale is lower), and variance is higher in the SP data than in the RP data, but the SP effects are lower in the second year of data collection. Turning to the utility function, some differences emerge. Although most parameters are qualitatively similar, they are scaled up disproportionately compared to those of the CPA models. As a result, the welfare measures are affected.

Finally, the parameters affecting availability are very similar to those of CPA models. Sites with higher CWD prevalence are more available to rural hunters, but not to urban hunters. The coefficient of $cwd \times yr2$ is not significant, again indicating that the effect of CWD on availability does not change in year 2.

Table 2.4: Implied Probabilities of Choice Set Size from the IAL Model

	Q (Probability)	
Number of alternatives	**IAL1**	**IAL2**
1	0.01	0.01
2	0.02	0.03
3	0.06	0.07
4	0.12	0.12
5	0.16	0.16
6	0.18	0.18
7	0.17	0.16
8	0.12	0.12
9	0.09	0.09
10	0.05	0.05
11	0.01	0.01
Total	1.00	1.00

Despite different models and specifications, there are some consistent results. The availability factor decreases with CWD for urban hunters. The overall effect of CWD for urban hunters is negative, but not statistically significant. For rural hunters, the availability factor increases with CWD. The effect of CWD in year 2 is not different from that of year 1. The effect of CWD on availability is different between rural and urban hunters, not between year 1 and year 2. However, CWD in year 2 in the utility function has negative coefficients across models and thus the CWD effect in the utility function appears to be different between year 1 and year 2 and seems to generate a strong welfare impact. The effect of CWD on availability doesn't change over time, but utility does. Finally, other coefficients in the utility function are also consistent in signs.

Table 2.4 shows that most hunters have a choice set size of 4-8 sites. Only a small fraction of the sample is likely to have choice sets of size 10 or 11. This implies the MNL models, which assume hunters have a full choice set, may be biased. However the results show that CPA model appears to be qualitatively consistent with the IAL models.

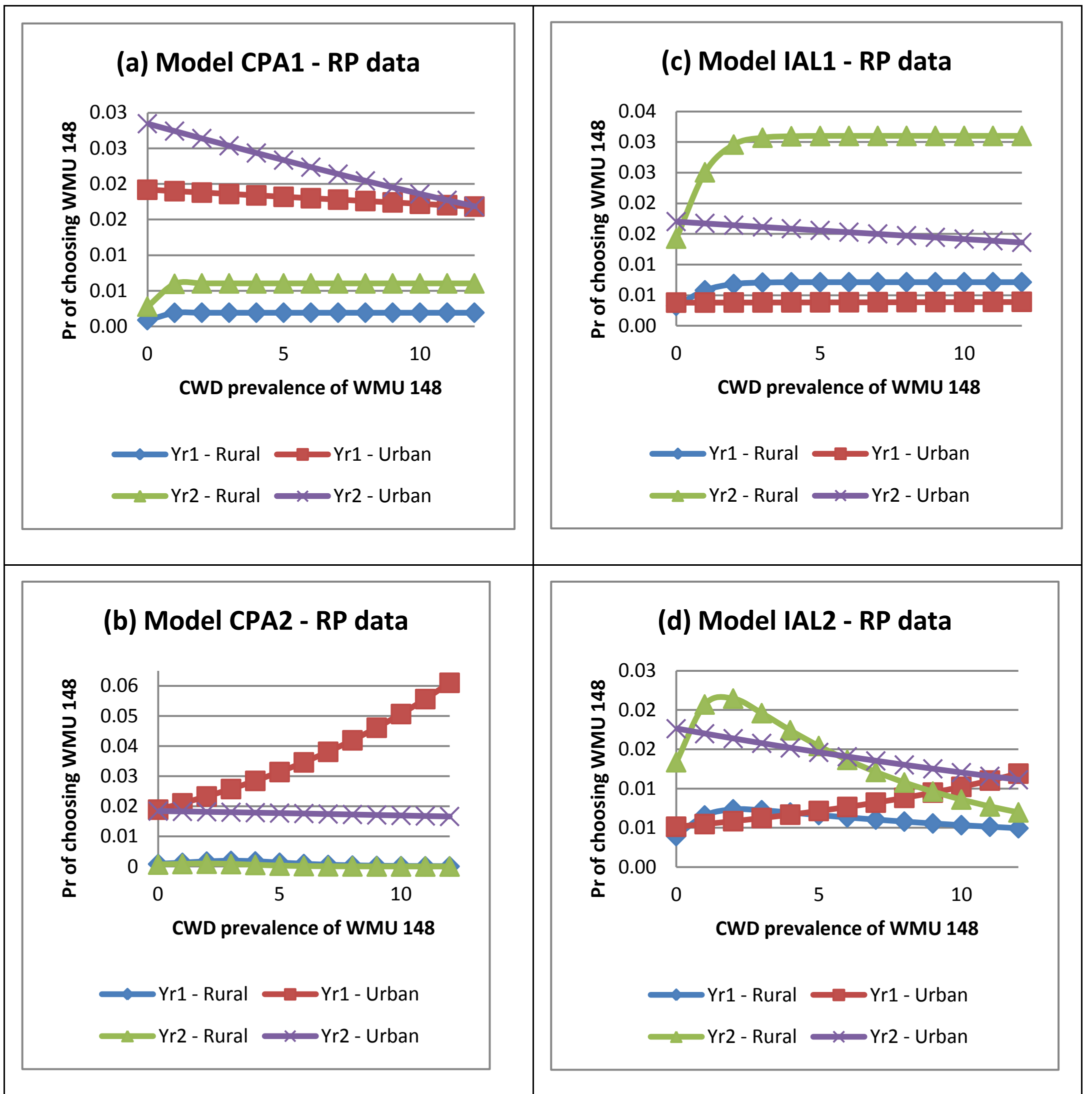

Figure 2.1: Probability of choosing WMU 148 as CWD prevalence changes

As mentioned above, CWD has different effects on choice set formation and evaluation, so it may be helpful to examine how it affects the probability of choosing a site. We illustrate this with WMU 148, a currently uninfected site, to see how the probability changes when its CWD prevalence varies from 0 to 12%, holding that of other sites unchanged. We use the sample average of hunting years (as it appears in the utility function).

Figures 2.1 presents the probabilities of choosing WMU 148 calculated from CPA and IAL models using RP data. Each panel presents the change in probability of choice by urban and rural hunters in the two years as the levels of CWD increases. The probabilities from CPA and IAL model for each specification show similar pattern although the magnitudes of probabilities are different. For model CPA1 and IAL1 (CWD variables in availability only), urban hunters appear to be less likely to choose the site if CWD increases and the effect of CWD on probabilities is higher in year 2. For rural hunters, probability of choosing WMU 148 initially increase with CWD prevalence up to 1-2% and is stabilized beyond the point, in both years.

For models CPA2 and IAL2 (CWD variables in both availability and utility functions), the probabilities of choosing WMU 148 also show similar pattern between the two models. Urban hunters tend to be more likely choose the site in year 1 when CWD prevalence increases. However in year 2, this probability decreases with CWD prevalence. The probability of rural hunters choosing the site initially increases when CWD increase, but then decreases.

2.4.3 Welfare Measures

We examine the welfare measures for the change from the current CWD prevalence situation and management actions to one in which CWD prevalence levels spread to what is expected in a "worst case scenario". The "worst case" scenario is characterized by a 12.5% CWD prevalence in WMUs 150, 151 and 234 (currently infected WMUs), 7.5% in WMUs 148, 162, 200, 236 and 500, and 2.5% in WMUs 163, 256 and 999, and as mentioned, no management activity (no culling, no additional tags) (see Zimmer *et al*. 2012 for more details). We examine the welfare impact on rural hunters, urban hunters, and an aggregate. For the models that include availability we also examine the proportion of the impact that arises from the utility function and the proportion from the choice set formation component.

For the CPA model, the welfare change of hunter i is calculated using the formula

$$E\left(CV_i\right)=\frac{1}{\beta_i}\left[\ln\left[\sum_{j=1}^{11}\exp\left(\frac{V_{ji}^1}{\mu_i}\right)\right]^{\mu_i}-\ln\left[\sum_{j=1}^{11}\exp\left(\frac{V_{ji}^0}{\mu_i}\right)\right]^{\mu_i}\right]$$

where β_i is the marginal utility of money of hunter i, V_{ji}^0 is the utility of site j to hunter i at the current management condition and V_{ji}^1 is the corresponding utility at the worst case scenario and μ_i is the scale factor. Note that the utility function is defined as in equation (2.8).

The case is more complicated in IAL model. For IAL models, given a choice set C_k, the compensating variation of changing from V^0 to V^1 is

$$E\left(CV_i\mid C_k\right)=\frac{1}{\beta_i}\left[\ln\left[\sum_{j\in C_k}\exp\left(\frac{V_{ji}^1}{\mu_i}\right)\right]^{\mu_i}-\ln\left[\sum_{j\in C_k}\exp\left(\frac{V_{ji}^0}{\mu_i}\right)\right]^{\mu_i}\right]$$

Change from V^0 to V^1 results from changes in attributes, which may also change the probabilities of all choice sets C_k. The total welfare change is

$$E\left(CV_i \mid C_k\right)=\frac{1}{\beta_i}\left[\begin{array}{l}\sum_{C_k \subseteq C_m} Q^1\left(C_k\right)\ln\left[\sum_{j\in C_k}\exp\left(\frac{V_{ji}^1}{\mu_i}\right)\right]^{\mu_i} \\ -\sum_{C_k \subseteq C_m} Q^0\left(C_k\right)\ln\left[\sum_{j\in C_k}\exp\left(\frac{V_{ji}^0}{\mu_i}\right)\right]^{\mu_i}\end{array}\right]$$

Table 2.5 presents the welfare impacts of the "worst case" scenario calculated from MNL, CPA and IAL models. The two columns for MNL models outline the impact when availability is not included in the analysis. The welfare impact is negative for hunters from urban areas, and for all hunters in year 2. The negative impact increases in absolute value in year two indicating a worsening of the perception of the effects of the disease.

For the model that includes availability (CPA and IAL) changing from the current situation to the worst case also reduces welfare of urban hunters in year 2. For rural hunters, the welfare reduces in cases of CPA2 and IAL2 models, but increase in cases of CPA1 and IAL1. Looking at model CPA2, the reduction is higher for rural hunters ($61.66/trip) than urban hunters ($25.98/trip). The welfare reduction in year 2 is higher than that in year 1. The welfare increases for urban hunters in year 1, largely because of the positive coefficient of $cwd \times urban$ in the utility function. The welfare changes are similar for model CPA2 and IAL2, and for model CPA1 and IAL1.

In Table 2.5 we also decompose the welfare change into separate contributions of the utility function and the availability function. The utility component is calculated by allowing a change in the utility function, while holding the availability factor fixed at the current management level. Similarly, the availability component is calculated by allowing availability factor change, holding utility fixed at the current management. The contribution of the availability function to welfare change is considerable in many cases, in some cases larger than the contribution from the utility function.

Table 2.5: Welfare Changes of Moving to the "Worst Case" Scenario

Model		MNL1	MNL2	CPA1	CPA2	IAL1	IAL2
Year 1 – Rural	Utility			0.49 (4.3)	-127.29 (30.41)	10.21 (4.98)	-10.32 (1.95)
	Availability			21.76 (7.15)	101.18 (11.89)	26.87 (25.48)	25.26 (23.97)
	Total	**15.37 (3.75)**	**15 (5.18)**	**21.98 (8.48)**	**-27.15 (28.49)**	**32.47 (21.77)**	**12.96 (24.72)**
Year 1 – Urban	Utility			2.7 (4.42)	237.21 (22.35)	10.41 (5.19)	43.25 (7.74)
	Availability			-4.61 (0.59)	-91.15 (10.39)	1.48 (0.22)	-14.88 (2.17)
	Total	**-4.24 (4.38)**	**-18.35 (4.73)**	**-2.06 (4.3)**	**66.76 (11.09)**	**11.95 (5.28)**	**26.19 (6.91)**
Year 2 – Rural	Utility			0.03 (6.27)	-221.92 (12)	15.05 (4.16)	-51.58 (1.69)
	Availability			11.03 (8.82)	111.71 (30.67)	9.41 (9.1)	10.17 (10.26)
	Total	**-11.23 (3.66)**	**-23.07 (6.28)**	**9.93 (12.93)**	**-61.66 (13.36)**	**20.67 (0.07)**	**-42.88 (8.71)**
Year 2 – Urban	Utility			0.57 (3.13)	51.58 (13.27)	8.85 (4.13)	3.64 (5.35)
	Availability			-22.27 (7.71)	-60.08 (20.38)	-9.59 (2.94)	-9.2 (2.97)
	Total	**-40.67 (4.74)**	**-49.93 (15.78)**	**-21.95 (7.75)**	**-25.98 (9.24)**	**-1.01 (5.6)**	**-5.86 (6.85)**

Note: Measures are in $/trip. Standard deviations are in parentheses.

2.5 DISCUSSION AND CONCLUSIONS

This paper compares a fully endogenous choice set model using the Independent Availability Logit model with the availability function approach that approximates choice set formation. It analyzes the response of Albertan hunters to CWD risk, in both stages of site choice evaluation and choice set formation. We employ a sample of hunters that might not be representative, but useful to illustrate the empirical approach. The analyses found mixed evidence that CWD affects utility parameters in site choice evaluation as well as on choice set formation.

However, there are some consistent results across models. First, availability factor decreases with CWD for urban hunters, while increases with CWD for rural hunters. Second, the effect of CWD in year 2 is not statistically different from that of year 1. In general, the effect of CWD on availability is not different between year 1 and year 2. It is just different between rural and urban hunters. The choice set formation contributions to total welfare changes are considerable in most cases.

However, CWD shows different effects in the utility function. Both CPA and IAL models shows that rural hunters appear to dislike CWD while urban hunters like sites with CWD. The CWD effect in the utility function appears to be different between year 1 and year 2 and seems to generate a strong welfare impact. Particularly, hunters appear to be less likely to like sites with higher CWD prevalence in year 2.

Our analyses can be helpful for making decisions on management strategies to combat CWD in Alberta. Zimmer *et al*. (2011) when analyzing hunter behaviors with data of the first hunting season of this study found that the impact of CWD on hunter behavior is not significant. On the other hand, Zimmer *et al*. (2012) when comparing their welfare measures of avoiding CWD in Alberta with the cost of the CWD management program, found that the cost of the program is likely greater than the benefit. Yet they argue that in the long run, if CWD was no longer present and no management was needed, the benefit would continue to accrue and would outweigh the costs that are experienced in early years. As hunters are found to be more likely to dislike CWD in year 2 in our analysis, they may be more likely to dislike CWD later on. As a result, the benefit of stopping the spread and prevalence of CWD will become larger over time. This implies that the benefit not only accrues but may also become larger if hunters change their preferences for CWD over time.

Finally, our comparison of the CPA and a fully specified IAL model provides some similar results. While the models are qualitatively similar for many parameters, it appears that the Cascetta and Papola approach generates a somewhat different set of parameters for the availability function or choice set formation. This is probably consistent with Bierlaire *et al*. (2010), which pointed out that the Cascetta and Papola model is sometimes a poor approximation of the formal choice set formation model.

The choice set formation models outperform models without choice set formation. They generate welfare measures that are quite different than models that do not include choice set formation. As a result, choice set formation processes should be included in choice models. Since the CPA model appears to be a poor approximation, the IAL model is more desirable despite its complexity in estimation. In addition, the CPA model sometimes generates very high welfare measures (in absolute values) contributed by the utility and/or availability functions. This may imply that the CPA model is fragile. This suggests that additional investigation of the structure of choice set formation, and the capability of choice set formation models to capture such processes, is required.

A number of conceptual and empirical issues arise from our investigation. These include:

1. Is it possible to construct a good a theory of choice set formation? Why do people form choice sets and can knowledge of this process inform the specification of choice set formation functions and analysis? Is formation of choice sets a mechanism for maintaining flexibility (Kreps, 1979) or is limiting

choice set size a mechanism to avoid regret (Sarver, 2008), suggesting that empirical representations of regret should focus on choice set structure rather than utility?

2. There is a relationship between choice set formation and non-compensatory preference structures (e.g. Swait 2001b, Hauser 2010). Further research aimed at untangling the difference between these two representations of choice processes and between "hard" and "soft" choice set boundaries is required.
3. What are the welfare implications of changes in attributes that affect choice set formation as well as utility, and monetary measures (such as travel costs) that enter choice set formation and utility? (see Manrai and Andrews (1998) for a discussion of similar issues in a marketing context).

Investigation of these issues will require theoretical and empirical analyses that may include analyses of actual and simulated data, as well as experimental research. What is clear, however, is that based on a likelihood ratio test, including choice set formation improves the statistical properties of choice models, and generates welfare measures that differ from models that exclude choice set generation. Therefore additional investigation into choice set formation properties appears warranted.

REFERENCES

Andrews, R. and T.C. Srinivasan. 1995. Studying consideration effects in empirical choice models using scanner panel data. *Journal of Marketing Research* 32: 30-41.

Başar, G. and C. Bhat. A Parameterized Consideration Set Model for Airport Choice: An Application to the San Francisco Bay Area. *Transportation Research B* 38:889-904.

Ben-Akiva M. and B. Boccara. 1995. Discrete choice models with latent choice sets. *International Journal of Research in Marketing* 12: 9-24.

Ben-Akiva, M. and S. R. Lerman. 1985. Discrete Choice Analysis: Theory and Application to Travel Demand. MIT, Cambridge.

Bierlaire, M. 2003. BIOGEME: A free package for the Estimation of Discrete Choice Models. Proceedings of the 3rd Swiss Transportation Research Conference. Ascona. Switzerland.

Bierlaire, M., R. Hurtubia and G. Flötteröd. 2010. Analysis of Implicit Choice Set Generation Using a Constrained Multinomial Logit Model. *Transportation Research Record* 2175: 92-97.

Bovy, P.H. 2009. On Modelling Rout Choice Sets in Transportation Networks: A Synthesis. *Transport Review* 29(1): 43-68.

Bunn, D.W. and F.S. Oliveira. 2001. Agent-based simulation: An application to the new electricity trading arrangements of England and Wales. *IEEE transactions on Evolutionary Computation* 5:493-503.

Cascetta, E., A. Papola, 2001. Random utility models with implicit availability/perception of choice alternatives for the simulation of travel demand. *Transportation Research Part C* 9(4): 249–263.

Chiang, J., S. Chib and C. Narasimhan. 1999. Markov chain Monte Carlo and model of consideration set and parameter heterogeneity. *Journal of Econometrics* 89: 223-248.

Clawson, M. 1959. Method for Measuring Demand for and the Value of Outdoor Recreation. Reprint No. 10. Washington, D.C.: Resources for the Future.

Diana, S.C., C.A. Bisogni and K.L. Gall. 1993. Understanding anglers' practices related to health advisories for sport-caught fish. *Journal of Nutrition Education* 25(6): 320-328.

Erev, I. and A.E. Roth. 1998. Predicting how people play games with unique, mixed strategy equilibria. *American Economic Review* 88: 848-81.

Federal-Provincial-Territorial Task Force on the Importance of Nature to Canadians. 2000. *The importance of nature to Canadians: the economic significance of nature related activities*. Minister of the Environment: Ottawa, Canada.

Government of Alberta. 2010. Sustainable Resources Development website. *Chronic Wasting Disease*. http://www.srd.alberta.ca/BioDiversityStewardship/WildlifeDiseases/ChronicWastingDisease/Default.aspx Accessed on 8 February 2011.

Haab, T.C. and R.L. Hicks. 1997. Accounting for choice set endogeneity in random utility models of recreation demand. *Journal of Environmental Economics and Management* 34(2): 127-147.

Haab, T.C. and R.L. Hicks. 1999. Choice Set Considerations in Models of Recreation Demand: History and Current State of the Art. *Marine Resource Economics* 14: 271-281.

Hanemann, W.M. 1978. A Methodological and Empirical Study of the Recreation Benefits from Water Quality Improvement. *Dissertation*. Department of Economics. Harvard University.

Hauser, J.R. 2010. Consideration-Set Heuristics. *Journal of Business Research,* Forthcoming.

http://web.mit.edu/hauser/www/Papers/Hauser%20Consideration%20Heuristics%20JBR%202011.pdf Assessed 10 May 2011.

Hicks, R.L. and K.E. Schnier. 2010. Spatial Regulations and Endogenous Consideration Sets in Fisheries. *Resource and Energy Economics* 32: 117-134.

Hicks, R.L. and I.E. Strand. 2000. The Extent of Information: Its Relevance for Random Utility Models. *Land Economics* 76(3): 374-385.

Hotelling, H. 1949. Letter to the National Park Service. In *An Economic Study of the Monetary Evaluation of Recreation in the National Parks.* Washington, D.C.: U.S. Department of the Interior, National Park Service and Recreational Planning Division.

Jakus, P.M., M. Downing, M.S. Bevelimer, and J.M. Fly. 1997. Do sportfish consumption advisories affect reservoir anglers' choice? *Agriculture and Resource Economics Review* 26(2): 196-204.

Jakus, P.M. and W.D. Shaw. 2003. Perceived hazard and product choice: An application to recreational site choice. *Journal of Risk and Uncertainty* 26(1): 77-92.

Jones, C. and F. Lupi. 1999. The effect of modelling substitute activities on recreational benefit estimates: Is more better? *Marine Resource Economics* 14: 357-74.

Kuriyama, K., W.M. Hanemann and L. Pendleton. 2003. Approximation Approaches to Probabilistic Choice Set Models for Large Choice Set Data. University of California, Berkeley, Working paper 967.

Kreps, D. 1979. A Preference for Flexibility, *Econometrica* 47, 565–576.

Manrai, A. K. and R. L. Andrews (1998), Two-stage discrete choice models for scanner panel data: An assessment of process and assumptions, *European Journal of Operational Research* 111: 193-215.

Manski, C.F. 1977. The Structure of Random Utility Models, *Theory and Decision* 8: 229-254.

Martinez, F., F. Aguila and R. Hurtubia. 2009. The constrained multinomial logit: A semi-compensatory choice model. *Transportation Research Part B* 43: 365-377.

May, H. and J. Burger. 1996. Fishing in a polluted estuary: fishing behaviour, fishing consumption, and potential risk. *Risk Analysis* 16(4): 459-471.

Murdock, J. 2006. Handling unobserved site characteristics in random utility models of recreation demand. *Journal of Environmental Economics and Management* 51 (1), 1–25.

Nicolaisen, J., V. Petrov, and L. Tesfatsion. 2001. Market power and efficiency in a computational electricity market with discriminatory double-auction pricing. *IEEE transactions on Evolutionary Computation* 5: 504-23.

Parsons, G. and A. Hauber. 1998. Spatial boundaries and Choice Set Definition in a Random utility model of Recreation Demand. *Land Economics* 74(1): 32-48.

Peters, T., W. Adamowicz and P. Boxall. 1995. The Influence of choice set consideration in modelling the benefits of improved water quality. *Water Resources Research* 613: 1781-7.

Roberts, J., J. Lattin. 1991. Development and testing of a model of consideration set composition. *Journal of Marketing Research* 28: 429-440.

Sarver, T. 2008. Anticipating Regret: Why Fewer Options May Be Better. *Econometrica* 76, 263-305.

Swait, J. 1984. Probabilistic choice set formation in transportation demand models. Dissertation. Department of Civil Engineering, MIT, Cambridge, MA.

Swait, J. 2001a. Choice set generation within the generalized extreme value family of discrete choice models. *Transportation Research Part B* 35(7): 643-666.

Swait, J. 2001b. A non-compensatory choice model incorporating attribute cut-offs. Transportation Research Part B 35(7) 903–928.

Swait, J. and M. Ben-Akiva. 1986. An analysis of the effects of captivity on travel time and cost elasticities. *Annals of the 1985 International Conference on Travel Behaviour. 16-19 April 1985*. Noordwijk, Holland. pp 113-128.

Swait, J. and M. Ben-Akiva. 1987a. Incorporating random constraints in discrete choice models of choice set generation. *Transportation Research B* 21(2): 91-102.

Swait, J. and M. Ben-Akiva. 1987b. Empirical test of a constrained choice discrete model: mode choice in Sao Paulo Brazil. *Transportation Research B* 21(2): 103-115.

Swait, J. and T. Erdem. 2007. Brand Effects on Choice and Choice Set Formation Under Uncertainty. *Marketing Science* 26(5): 679-697.

Swait, J. and J.J. Louviere. 1993. Role of the scale parameter in the estimation and comparison of multinomial logit models. *Journal of Marketing Research* 30(3): 305-314.

Timmins, C. and J. Murdock. 2007. A Revealed Preference Approach to the Measurement of Congestion in Travel Cost Models, *Journal of Environmental Economics and Management* 53(2): 230–249.

von Haefen, R.H. 2008. Latent consideration sets and continuous demand systems. *Environmental and Resource Economics* 41(3): 363-379.

Zimmer, N.M.P. 2009. The Economic Impacts of Chronic Wasting Disease on Hunting in Alberta. *Thesis*. Department of Rural Economy. University of Alberta.

Zimmer, N.M.P., P.C. Boxall, and W.L. Adamowicz. 2012. The Impacts of Chronic Wasting Disease and its Management on Hunter Perception, Opinions, and Behaviors in Alberta, Canada. *Journal of Toxicology and Environmental Health Part A* 74: 1621-1635.

Zimmer, N.M.P., P.C. Boxall, and W.L. Adamowicz. 2012. The Impacts of Chronic Wasting Disease and its Management on Recreational Hunters. *Canadian Journal of Agricultural Economics* 60(1): 71-92.

CHAPTER 3: MODELLING NON-COMPENSATORY PREFERENCES IN ENVIRONMENTAL VALUATION

The compensatory preference model has been dominant in environmental valuation and more generally in choice modeling as it is straightforward to estimate and interpret. This model assumes that subjects evaluate all attributes of alternatives presented and that a change in one attribute can be compensated for by a change in another attribute. However, non-compensatory preferences may better reflect choice behavior. There could be cases where an alternative with an attribute that has not satisfied a certain level ("cutoff") will always be rejected regardless of the levels of other attributes. This is an example of a conjunctive decision rule proposed by Coombs (1964) and Dawes (1964). The presence of non-compensatory decision processes has been empirically tested by many authors, including Bettman and Park (1980), Gensch and Svetska (1984), Lussier and Olshavsky (1979), Einhorn, Kleinmuntz and Kleinmuntz (1979), Payne (1976), Grether and Wilde (1984), Klein (1983), Klein and Bither (1987), Huber and Klein (1991), Cascetta and Papola (2001), Swait (2001) and Martinez *et al*. (2009). In many cases, the non-compensatory models are found to provide better representations of choice behavior.

However, in almost all of the literature employing non-compensatory frameworks, a cutoff is elicited directly from respondents (e.g. "I would pay no more than $X."). In other words, respondents are asked to state cutoffs along with their choices of alternatives in stated preference cases. Asking subjects for their own cutoff levels may be straightforward, however, such elicitation could be suspect as subjects may be unable to report their decision strategies accurately (Nisbett and Wilson, 1977), or may adapt their strategies to fit the choice context (Payne *et al*. 1988). In addition, the methods of collecting these data might introduce bias to the decision process in several ways (Elrod *et al*. 2004).

Parameters on self-reported cutoffs are also subject to endogeneity as there is possible correlation between reported cutoffs and the error term. There was evidence that assuming cutoffs to be exogenous may be inappropriate. Ding (2010) tested for endogeneity by comparing models with predicted cutoffs (from regressions of self-reported cutoffs on demographics) to models with self-reported cutoffs and found that endogeneity affects some of the estimated parameters. Klein and Bither (1987) found that cutoffs are affected by various factors including utility level, context and setting of the choices problem, and at times, respondents are willing to violate their stated cutoffs. Therefore, cutoffs may be correlated with the error terms of the utility function and thus assuming exogenous cutoffs may be incorrect.

In this paper we develop a model that can be used to estimate cutoff levels endogenously. Our model employs "soft" cutoffs, which imply that alternatives that violate the cutoff will be penalized in terms of utility rather than being eliminated from the choice set. Many of those using self-reported cutoffs also observed that subjects violated their self-reported cutoffs (see Klein and Bither 1987, Huber and Klein 1991 and Swait 2001 for example). Thus a soft cutoff may be a more appropriate way to model choice behavior. The model with soft cutoff is more flexible. If the penalty on a cutoff violation is zero, it collapses to a perfectly compensatory model. If the penalty is large enough, it effectively works as a hard cutoff model. The soft cutoff is characterized by a kinked utility function and indifference curve.

Assume an individual must choose one from a set of C goods. The model can be described as follows (based on Swait, 2001). The individual is assumed to maximize an objective function consisting of regular utility from the vector of attributes associated with alternative j (X_j) and utility penalties in the case of cutoff violations. The lower cutoff violation is defined as the positive difference of the lower cutoff compared to the attribute level, and the upper cutoff violation is defined as the positive difference of an attribute compared to its upper cutoff level. In additional to preference parameters associated with X_j, parameters on the cutoff violations are also estimated describing the penalty in utility terms associated with cutoff violations. If the decision maker applies a conjunctive strategy, for example, the parameters on cutoff violations are marginal penalties for violations of cutoffs and should be negative.

In our approach the error terms of the cutoff function are modeled explicitly. As a result, the model has two error components: one for the utility function, which is the commonly assumed Gumbel distributed error, and one for the cutoff function. This facilitates the estimation of the cutoff directly as a function of demographic variables (assumed to be exogenous). To the best of our knowledge, this approach to estimating cutoffs directly has not been employed in the literature.

We assume a Poisson distribution for cutoffs, which are assumed to fall into discrete categories, and estimate parameters for the utility function and the cutoff function. We estimate the model by maximizing the log-likelihood function that involves the weighted sum of two error components e_j (Gumbel distributed) and u_i (Poisson distributed). The log-likelihood function is derived by taking convolutions of the two distribution functions.

We test the model using synthetic data to ensure that it can provide reasonable estimates of the true parameters. Estimated parameters are very close to the true parameters. We then apply the model to an empirical data set and compare the cutoffs estimated from our models with stated cutoffs. Data for this part of the analysis are from a province wide survey in Alberta, Canada on conservation strategies for woodland caribou, which is a "Threatened" species (COSEWIC, 2002, ASRD and ACA, 2010). Respondents are asked to evaluate caribou conservation alternatives based on two attributes: the extent to which caribou are conserved (number of sustainable caribou herds) and the associated cost of conservation. Groups of respondents were invited to a central facility, presented with background information and then asked to make several choices. In each choice, respondents have to choose one from two management strategies. Respondents were also asked to provide their cutoffs associated with cost and caribou herds. A total of 956 responses to the stated preference questions are analyzed.

This case study also makes an empirical contribution. Because woodland caribou are listed as "Threatened", it is required by the *Species At Risk Act* in Canada that a species action plan with estimated costs and benefits must be created. By estimating the willingness to pay for woodland caribou conservation, this study provides a measure of the benefits generated by protecting the species. It provides information on the cutoff levels of cost and caribou herds, particularly the maximum acceptable amount each household is willing to pay and the minimum acceptable number of caribou herds, which can be useful for designing management strategies and for comparing to the costs of management options.

Our model appears to provide a better fit than the compensatory preference model. However, the estimated parameters and cutoff levels from our model are somewhat different compared to those from the self-reported cutoff model. The coefficients of the cutoff functions from our model are consistent with those from direct regression of stated cutoffs on demographics. In addition, estimated bid cutoffs are very close to self-reported bid cutoffs. However estimated herd cutoffs are significantly lower than self-reported herd cutoffs.

Our approach provides a tractable way to estimate non-compensatory preferences without relying on stated cutoffs. It explicitly models cutoff errors. It is relevant to cases where compensatory preferences may not be appropriate, and where analysts wish to estimate cutoffs without the information of stated cutoffs. Our empirical analysis illustrates that stated and estimated cutoffs yield somewhat different results, highlighting the need for an approach that does not rely on stated cutoff information.

3.1 LITERATURE REVIEW

The existence of cutoffs implies that decision makers set minimum levels required for relevant attributes to satisfy in order to be further evaluated. A cutoff provides the basis for two famous decision strategies: elimination by aspects (Tversky 1972) and the conjunctive decision rule (Coombs 1964 and Dawes 1964).

Tversky (1972) demonstrated that a decision maker when making a multiple alternative choice will consider the alternative a set of aspects. At each stage of choice, she or he will select an aspect and eliminate the alternatives that do not include the aspect. The process continues until only one alternative remains.

The conjunctive decision strategy is another non-compensatory rule, which was initially discussed by Coombs (1964) and Dawes (1964). The conjunctive rule suggests that decision makers set up cutoffs for attributes and alternatives must satisfy all cutoffs to be considered acceptable for further evaluation. The conjunctive choice rule was made popular by Einhorn (1970), who proposed nonlinear models for analyzing this non-compensatory rule, and Wright (1975) who analyzed the tradeoff between optimizing and simplifying the decision process.

Several researches have confirmed the existence of cutoffs. Bettman and Park (1980) found consistent results that subjects applied a conjunctive rule. Payne (1976) examined apartment choice strategies and found that when facing two-alternative choices, compensatory rules are used, while in multi-alternative choices, subjects applied strategies with cutoffs to quickly eliminate some alternatives. Lussier and Olshavsky (1979) found that when facing more than three alternative options, decision makers appear to eliminate alternatives using non-compensatory rules and then apply a compensatory rule to evaluate the retained alternatives. Grether and Wilde (1984) developed a theoretical framework and experimental design to test for the conjunctive choice rule and found that subjects conform to a certain conjunctive rule.

Klein (1983) found that subjects applied some non-compensatory rules and that cutoffs were specified a priori. Klein and Bither (1987) found that subjects choose cutoff levels at the points that maximize the utility difference between the two sets of alternatives: those that are retained and rejected. Huber and Klein (1991) also found evidence that subjects applied non-compensatory rules with cutoffs to reduce the number of alternatives, while applying compensatory rules to make the final choice.

Among research on cutoffs, Gensch and Svetska (1984), Elrod *et al*. (2005) and Martinez *et al*. (2009) are the ones that, to the best of our knowledge, were able to estimate the cutoff levels without knowing them, or having a stated measure of them, in advance. Other papers identify cutoffs by asking subjects whether they apply cutoffs on attributes and what are the levels of these cutoffs. Gensch and Svetska (1984) estimated aggregate cutoff levels, which are not individually specific. As a result, they cannot relate the cutoffs to individual characteristics. Elrod *et al*. (2004) provide a functional form for the utility function that allows for estimating the cutoff points. Martinez *et al*. (2009) provide a framework for estimating individual cutoffs. In almost all of the literature employing non-compensatory models, cutoffs information is collected directly from respondents.

Although the use of stated cutoff levels is widely adopted, several researchers also found that subjects at times violate their self-reported cutoffs (Huber and Klein 1991, Swait 2001). In addition, the cutoffs sometimes were not applied for a real non-compensatory decision strategy. In Lynch's (1983) experiment, subjects did not make decisions in a manner that is consistent with a true conjunctive process, but rather a "partially compensatory" rule. Subjects failed to classify alternatives into acceptable and unacceptable sets using cutoffs. Einhorn, Kleinmuntz and Kleinmuntz (1979) concluded that cutoffs may work as part of a compensatory decision process. This evidence suggests that the violation of cutoffs may not result in elimination, but rather a penalty in terms of utility. This is the basis for soft cutoffs, that is, alternatives that violate cutoffs should be penalized, not removed. We explore this approach, as implemented by Swait (2001), in more detail below.

Parameters estimated using models with self-reported cutoffs may also be subject to bias due to endogeneity. Ding (2010) tested for endogeneity by comparing models with predicted cutoffs to models with self-reported cutoffs. In the model with predicted cutoffs, instrumental variables for cutoffs were used to predict the cutoffs using individual characteristics, and then the predicted values were used for the choice model. The results show that subjects penalized alternatives with cutoff violations and that endogeneity affected some of the estimated parameters.

This paper proposes a model that estimates the cutoffs as functions of individual characteristics, based on the theoretical model of Swait (2001). When estimating the cutoff function, we also explicitly model the error terms of the cutoff function. We present Swait's model below, and the proposed model in the following section.

3.1.1 Swait's model

Swait (2001) developed a model in which violations of cutoffs result in utility penalties. Assume that an individual must choose one from a set of C goods. The model could be presented as follows:

$$\max U = \sum_{j \in C} \delta_j U\left(X_j\right) + \sum_{j \in C} \sum_k \delta_j \left(w_k \chi_{jk} + v_k \kappa_{jk}\right)$$

s.t. $$\sum_{j \in C} \delta_j = 1 \qquad \sum_{j \in C} \delta_j c_j \leq Y \qquad (3.1)$$

$$\delta_j \left(\theta_k^L - X_{jk}\right) - \chi_{jk} \leq 0 \qquad \forall j \in C, \forall k$$

$$\delta_j \left(X_{jk} - \theta_k^U\right) - \kappa_{jk} \leq 0 \qquad \forall j \in C, \forall k$$

$$\delta_j = 0,1, \ \chi_{jk} \geq 0, \ \kappa_{jk} \geq 0 \qquad \forall j \in C, \forall k$$

The objective function consists of two parts. One is utility obtained from the vector of attributes X_j of good j. The second part consists of a set of utility penalties that occur in the case of cutoff violations. Note $\theta^L = [a_1, ..., a_K]$ and $\theta^U = [b_1, ..., b_K]$ are the sets of lower and upper cutoffs of attributes. Variable χ_{jk} is the lower cutoff violation, defined as the difference between the level of attribute k and its lower cutoff level, and κ_{jk} the upper cutoff violation, defined as the difference of attribute k and its upper cutoff level, while w_k and v_k are corresponding parameters. If the decision maker applies a conjunctive strategy, w_k and v_k are marginal penalties for violations of cutoffs and should be negative. If they are zero, the model collapses to the standard model where there is no cutoff. The first constraint indicates that only one good is chosen and c_j is the cost of alternative j in the income (Y) constraint. The second and third constraints define the lower and upper cutoff violations.

Swait's model is consistent with elimination-by aspect and conjunctive decision strategies. As he states, elimination of alternatives that do not satisfy the constraints and then choosing the utility-maximizing one among remained alternatives is essentially the same as choosing the optimal one given the constraints.

3.2 ENDOGENEOUS CUTOFF MODEL

Cutoffs in Swait's model are assumed to be exogenous. The model includes cutoff violations in the utility function together with other attributes. Utility of individual i from alternative j is

$$U_{ij} = \sum_k \beta_k X_{ijk} + \sum_k w_k \chi_{ijk} + \sum_k v_k \kappa_{ijk} + \varepsilon_{ij} \tag{3.2}$$

and is estimated using a standard MNL model. Note that the violations are defined as

$$\chi_{ijk} = \max\left(0, \theta_{ik}^{L} - X_{ijk}\right) \quad \text{lower cutoff violations} \tag{3.3a}$$

$$\kappa_{ijk} = \max\left(0, X_{ijk} - \theta_{ik}^{U}\right) \quad \text{upper cutoff violations} \tag{3.3b}$$

To make the cutoffs endogenous and analyze the correlation between individual characteristics and cutoffs, the cutoffs can be made a function of individual characteristics

$$\theta_{ik} = \theta_{k}\left(z_i\right) \tag{3.4}$$

Given an appropriate specification and functional form for (3.4) the model defined by (3.2), (3.3) and (3.4) can be estimated using a nonlinear MNL approach. However, this model assumes no error in the cutoff function. The error of the cutoff function should capture the variations that are not explained by explanatory variables z_i. If cutoff errors exist, these errors will be added to the error term of the utility function to form a total error term. In a MNL model, this total error is assumed to be Gumbel distributed. This may be inappropriate as the error associated with utility will include stochastic elements from the cutoff function.

In this section we model the cutoff error in a modified binary logit framework, as the data we analyze have two alternatives. We start with a single attribute X_h ($k \equiv h$) with a lower cutoff. However the model can be expanded easily to allow for lower or upper cutoffs of several attributes. For notation simplification, we suppress the subscript i in this section. Note also that the attributes we employ are quantitative and cutoffs can be viewed as maximum or minimum acceptable levels of these attributes.

The assumed distribution of the cutoff significantly affects the complexity of model as the likelihood function involves the convolution of the two error terms. A Poisson distribution makes this model tractable. In addition, it is suitable for the attribute *herd* of our data, which is an integer. Assume a Poisson distribution for the cutoff of X_h

$$p_H = \Pr\left(\theta_h^L = H\right) = \frac{\lambda_h^H e^{-\lambda_h}}{H!} \quad \lambda_h > 0 \tag{3.5}$$

H takes non-negative integer values $H = H_l, H_l + 1, H_l + 2, ..., H_u$, where H_l and H_u are lower and upper bounds of attribute X_h. The cutoff λ_h can be parameterized by setting

$$\lambda_h = \hat{\theta}_h(z) = e^{\gamma_h z} \tag{3.6}$$

where z is a vector of individual characteristics (no alternative-specific variables) and γ_h are corresponding parameters. We know that $\lambda_h = e^{\gamma_h z}$ is the expected cutoff, which is not necessarily an integer.

A cutoff violation depends on the expected cutoff and X_{jh} which is the value of attribute X_h offered by alternative j. The estimated violation is

$$\hat{\chi}_j = \max\left(0, \lambda_h - X_{jh}\right) \tag{3.7}$$

And the actual violation is

$$\chi_j = \max\left(0, \theta_h^L - X_{jh}\right) \tag{3.8}$$

The error term of the cutoff is the difference between the actual and estimated cutoff

$$u_j = \chi_j - \hat{\chi}_j = \max\left(0, \theta_h^L - X_{jh}\right) - \max\left(0, \lambda_h - X_{jh}\right) \tag{3.9}$$

Consider the case with two alternatives $j = 0,1$ .The difference of cutoff errors between the two alternatives is

$$u = u_1 - u_0$$

$$= \max\left(0, \theta_h^L - X_{1h}\right) - \max\left(0, \lambda_h - X_{1h}\right) - \left[\max\left(0, \theta_h^L - X_{0h}\right) - \max\left(0, \lambda_h - X_{0h}\right)\right]$$

(3.10)

Note that u has a discrete distribution. Each value u_H has the probability of occurring p_H as defined in (3.5).

With two alternatives $j = 0,1$, the utility function with cutoffs can be written as

$$U_j = \beta X + w\left(\hat{\chi}_j + u_j\right) + \varepsilon_j \qquad (3.11)$$

where X is a vector of attributes including X_h, ε_j is the conventional Gumbel distributed error term, $\hat{\chi}_j$ is the estimated cutoff violation and u_j is the error term generated from the cutoff violation. The probability of choosing alternative 1 over 0 is

$$\Pr\left(y = 1\right) = \Pr\left(U_1 - U_0 \geq 0\right)$$

$$\Pr\left(y = 1\right) = \Pr\left(\varepsilon_1 - \varepsilon_0 + wu_1 - wu_0 \leq \beta\left(X_1 - X_0\right) + w\left(\hat{\chi}_1 - \hat{\chi}_0\right)\right) \qquad (3.12)$$

Let

$$\pi = \beta\left(X_1 - X_0\right) + w\left(\hat{\chi}_1 - \hat{\chi}_0\right) \qquad (3.13)$$

And $\varepsilon = \varepsilon_1 - \varepsilon_0$ and $u = u_1 - u_0$. The probability of choosing alternative 1 becomes

$$\Pr\left(y = 1\right) = \Pr\left(\varepsilon + wu \leq \pi\right) \qquad (3.14)$$

Note that if ε_0 and ε_1 are Gumbel distributed with location parameter 0 and scale parameter 1, then ε is logistically distributed with the cumulative distribution function

$$\Lambda(\varepsilon) = \frac{1}{1+e^{-\varepsilon}} \tag{3.15}$$

Recall that u has a discrete distribution with each value u_h has a probability of occurring p_h. The sum of two error terms in (3.14) is the convolution of the two distribution functions, one is logistic, and one is discrete

$$\Pr(y=1) = \sum_{H=H_l}^{H_u} \Pr(\varepsilon + wu_H \le \pi)\, p_H \tag{3.16}$$

Or

$$\Pr(y=1) = \sum_{H=H_l}^{H_u} \Pr(\varepsilon \le \pi - wu_H)\, p_H \tag{3.17}$$

Therefore

$$\Pr(y=1) = \sum_{H=H_l}^{H_u} \Pr(\varepsilon \le \pi - wu_H) \frac{\lambda_h^H e^{-\lambda_h}}{H!} \tag{3.18}$$

where $\pi = \beta(X_1 - X_0) + w(\hat{\chi}_1 - \hat{\chi}_0)$, and $\lambda_h = e^{\gamma_h z}$, and u_H is defined by (3.10).

Note that below the smallest value and beyond the highest value of X_h used in the experiment, a change in cutoff does not change u_H because the cutoff violations of the two alternatives will change by the same amount and cancel out. As a result, the probability that the cutoff equals the highest value can be set at

$$p_{H_u} = 1 - \sum_{H=H_l}^{H_u - 1} \frac{\lambda_h^H e^{-\lambda_h}}{H!}$$

This will ensure that the sum $\sum_{H=H_l}^{H_u} \frac{\lambda_h^H e^{-\lambda_h}}{H!} = 1$. Similar rules apply to the probabilities of H that are smaller than the smallest value used, but keep in mind that H must be non-negative.

Parameters to be estimated include β, w, and γ. The likelihood function is

$$L = \prod_{i=1}^{N} \left[\sum_{H=H_l}^{H_u} \Lambda\left(\pi_i - wu_{Hi}\right) \frac{\lambda_{hi}^H e^{-\lambda_{hi}}}{H!} \right]^{y_i} \left[1 - \sum_{H=H_l}^{H_u} \Lambda\left(\pi_i - wu_{Hi}\right) \frac{\lambda_{hi}^H e^{-\lambda_{hi}}}{H!} \right]^{1-y_i} \quad (3.19)$$

where y_i is the choice of individual i. The log-likelihood function is

$$LL = \sum_{i=1}^{N} \left\{ \begin{array}{l} y_i \ln \left[\sum_{H=H_l}^{H_u} \Lambda\left(\pi_i - wu_{Hi}\right) \frac{\lambda_{hi}^H e^{-\lambda_{hi}}}{H!} \right] + \\ +\left(1 - y_i\right) \ln \left[1 - \sum_{H=H_l}^{H_u} \Lambda\left(\pi_i - wu_{Hi}\right) \frac{\lambda_{hi}^H e^{-\lambda_{hi}}}{H!} \right] \end{array} \right\} \quad (3.20)$$

Adding upper cutoffs for attribute X_b to the above model is straightforward. Again we assume a Poisson distribution

$$p_B = \Pr\left(\theta_b^U = B\right) = \frac{\lambda_b^B e^{-\lambda_b}}{B!} \qquad \lambda_b > 0, \; B = B_l, B_l + 1, B_l + 2, ..., B_u \quad (3.21)$$

Similarly we can parameterize the model by setting $\lambda_b = \hat{\theta}_b\left(z\right) = e^{\gamma_b z}$. The utility function is now

$$U_j = \beta X + w\left(\hat{\chi}_j + u_j\right) + v\left(\hat{\kappa}_j + \omega_j\right) + \varepsilon_j \quad (3.22)$$

The difference of cutoff errors of the two alternatives is

$$\omega = \omega_1 - \omega_0$$

$$\begin{aligned} &= \max\left(0, X_{1b} - \theta_b^U\right) - \max\left(0, \lambda_b - X_{1b}\right) \\ &-\left[\max\left(0, X_{0b} - \theta_b^U\right) - \max\left(0, \lambda_b - X_{0b}\right)\right] \end{aligned} \tag{3.23}$$

The probability of choosing alternative 1 is now

$$\Pr\left(y=1\right) = \sum_{H=H_l}^{H_u} \sum_{B=B_l}^{B_u} \Lambda\left(\pi - wu_H - v\omega_B\right) \frac{\lambda_h^H e^{-\lambda_h}}{H!} \frac{\lambda_b^B e^{-\lambda_b}}{B!} = P \tag{3.24}$$

where $\pi = \beta\left(X_1 - X_0\right) + w\left(\hat{\chi}_1 - \hat{\chi}_0\right) + v\left(\hat{\kappa}_1 - \hat{\kappa}_0\right)$, and $\lambda_b = e^{\gamma_b z}$, and ω_B is defined by (3.23). The log-likelihood function becomes

$$LL = \sum_{i=1}^{N} y_i \ln P + \left(1 - y_i\right) \ln\left[1 - P\right] \tag{3.25}$$

where P is defined by (3.24).

3.3 DATA

Data for the paper are obtained by observing choices of caribou conservation options. Respondents are asked to evaluate caribou conservation alternatives based on two attributes: the extent to which caribou are conserved (number of self-sustaining herds) and the cost of conservation. In each choice, respondents are asked to choose between two strategies: the current management strategy and a proposed one. The proposed management strategy is one that provides more self-sustaining caribou herds by several measures including restrictions on resource extraction industries, predator management and growing forest, and is drawn from a set of strategies providing different number of self-sustaining herds at various cost levels. See Harper (2012) for detailed information about the data.

In another type of choice, respondents are also asked to choose between two proposed management strategies (not including the current management strategy). This is because it may be required by law to do something to protect woodland caribou – implying that a no cost “status quo” is impossible. In this second approach respondents are presented with pairs of management options, each defined by an annual cost and a number of caribou herds conserved.

Several focus group discussions were held to test the survey instruments before the final survey was implemented. Respondents were selected randomly from major centers in Alberta, including Edmonton, Calgary, Grande Prairie, and Lloydminster. Groups of about 30-40 subjects were invited to a location where they were introduced to the issues with an information presentation (as a PowerPoint presentation) about caribou and conservation strategies. After that they were asked to answer the questionnaire. The questionnaire also asks about demographic information and a number of opinions about conservation activities. See Appendix 2 for the PowerPoint presentation and questionnaire.

As mentioned, the attributes are *herd* and *bid*. The levels of *herd* are 2, 3, 6, 9, 13 (self-sustaining herds) and the levels of *bid* are $0, $5, $50, $75, $150, $300 and $600. We also employ *sq* as an attribute, which is a dummy variable indicating whether the alternative is the current management strategy. In addition, we also collect demographic information.

Each respondent made four choices, including two votes between the current management strategy and a proposed strategy, and two choices between two proposed strategies. A total of 259 respondents completed the survey, which provides 1,036 choice observations. Of the 258 respondents, 105 are from Edmonton, 76 from Calgary, 43 from Grande Prairie and 34 from Lloydminster. After removing missing observations, 956 choice observations remain, including 481 votes and 475 choices.

The model is estimated using the authors' MATLAB code. As the model may have multiple solutions, for each run we perform a global search for an acceptable optimal solution using MATLAB's Global Optimization Toolbox.

3.4 SIMULATION WITH SYNTHETIC DATA

To test the proposed model, we estimate it using synthetic data. The synthetic data are generated using the real data, with assumed coefficients. Column 2 of Table 3.1 presents the assumed coefficients for the utility function and cutoff functions. We assume a lower cutoff for caribou herd and upper cutoff for bid. Herd cutoff is assumed to be a function of *yliving* (years living in Alberta), and bid cutoff a function of *income*, both with a constant

$$\lambda_h = e^{\gamma_0 + \gamma_1 yliving} \qquad \lambda_b = e^{\varphi_0 + \varphi_1 income} \tag{3.26}$$

The attributes, *yliving* and *income* are taken from the real data. The utility of each alternative in the data is calculated using the attributes and violations, based on the assumed coefficients, with a Gumbel distributed error added. The choice variable is then generated using the calculated utility. This choice variable is then used as the dependent variable in the estimation of two models. One is the binary logit model with calculated cutoffs, one with the proposed model. In the model with calculated cutoffs, we estimate a binary logit model with the choice variable on attributes and cutoff violations, where cutoff violations are calculated using equation (3.26) rounded to the closest integer. In this case the cutoff violations are assumed to be "exogenous".

We then estimate the "true" parameters using the proposed model by maximizing the log-likelihood function

$$LL = \sum_{i=1}^{N} y_i \ln P + (1 - y_i) \ln[1 - P] \tag{3.27}$$

Where

$$P = \Pr(Y = 1) = \sum_{H=0}^{15} \sum_{B=0}^{60} \Lambda(\pi - wu_H - v\omega_B) \frac{\lambda_h^H e^{-\lambda_h}}{H!} \frac{\lambda_b^B e^{-\lambda_b}}{B!} \tag{3.28a}$$

$$\pi = \beta(X_1 - X_0) + w(\hat{\chi}_1 - \hat{\chi}_0) + v(\hat{\kappa}_1 - \hat{\kappa}_0) \tag{3.28b}$$

$$\lambda_h = e^{\gamma_0 + \gamma_1 yliving} \qquad \lambda_b = e^{\varphi_0 + \varphi_1 income} \tag{3.28c}$$

$$u_H = \max(0, H - X_{1h}) - \max(0, \lambda_h - X_{1h}) - [\max(0, H - X_{0h}) - \max(0, \lambda_h - X_{0h})]$$

(3.29)

$$\omega_B = \max(0, X_{1b} - B) - \max(0, \lambda_b - X_{1b}) - [\max(0, X_{0b} - B) - \max(0, \lambda_b - X_{0b})]$$

(3.30)

In this model the herd cutoff has a Poisson distribution

$$p_H = \Pr(\theta_h^L = H) = \frac{\lambda_h^H e^{-\lambda_h}}{H!} \tag{3.31}$$

where $H = 0, 1, 2, \ldots, 15$. We discretize the bid cutoff by assuming it takes discrete values from \$0 to \$600 with increments of \$10, and thus $B = 0, 1, 2, \ldots, 60$ (in \$10 increments). As a result the distribution of the bid cutoff can be approximated by

$$p_B = \Pr(\theta_b^U = B) = \frac{\lambda_b^B e^{-\lambda_b}}{B!} \tag{3.32}$$

where $B = 0, 1, 2, \ldots, 60$.

Table 3.1 presents the true parameters and the estimated coefficients from the two models. In the binary logit model, the cutoff violations are calculated by using the attributes and the cutoffs defined by (3.26). In other words, cutoff violations enter this model as exogenous.

Table 3.1: True parameters and estimation results

Variable	True parameter	ESTIMATED COEFFICIENTS Binary Logit without cutoff	Binary Logit with stated cutoffs	Proposed model
	UTILITY FUNCTION			
'ASC – status quo'	-2	-2.226 (0.259)	-2.451 (0.314)	-2.541 (0.349)
'bid'	-0.15	-0.182 (0.014)	-0.163 (0.019)	-0.167 (0.046)
'herd'	0.25	0.152 (0.033)	0.229 (0.045)	0.246 (0.354)
Violation of herd cutoff	-0.5		-0.574 (0.093)	-0.557 (0.095)
Violation of bid cutoff	-0.25		-0.267 (0.038)	-0.269 (0.334)
	HERD CUTOFF FUNCTION			
Constant	-3			-2.939 (1.15)
Years living in Alberta	0.1			0.098 (0.031)
	BID CUTOFF FUNCTION			
Constant	-4			-4.619 (5.099)
Income ($10,000)	0.5			0.547 (0.471)

Note: Standard errors are in parentheses.

The last column of Table 3.1 presents the estimation results applying the proposed model. Except ASC, all other estimated coefficients are not statistically different from the true parameters. The estimated coefficients of both models are slightly larger than the true parameters.

Table 3.2 presents the choice predictions using true parameters, binary logit with stated cutoffs and the proposed model. The percentages of correct predictions of the three sets of parameters are very close. This again shows good predictive power of the proposed model.

Table 3.2: Prediction using estimated models for synthetic data

	True parameter		ESTIMATED					
			Binary Logit without cutoff		Binary Logit with stated cutoffs		Proposed model	
	Predict = 0	Predict = 1	Predict = 0	Predict = 1	Predict = 0	Predict = 1	Predict = 0	Predict = 1
Choice = 0	387	47	384	49	388	46	388	46
Choice = 1	13	509	27	496	15	507	14	508
% correct	**93.7**		**92.0**		**93.6**		**93.7**	

3.5 ESTIMATION WITH REAL DATA

As described above, the actual data include 241 individuals making 956 choices, of which 481 are votes (choices between status quo and a proposed management strategy), and 475 choices (choices between two management strategies). Table 3.3 presents summary statistics of individual characteristics variables used for regressions.

Table 3.3: Statistics

	Mean	Std. Dev.	Min	Max
Age	48.18	14.7	18	87
Years living in Alberta	32.6	18.72	1	80
Income ($10K/year)	8.94	4.67	1	17
Dummy variables				
Male	0.52			
College or higher	0.54			
Fulltime worker	0.49			
Often watch TV programs about animals	0.39			
Hunting in the past 12 months	0.10			

Table 3.4 presents estimation results for simple MNL models. Models MNL1 and MNL2 are basic MNL models, one with attributes only and one includes interactions (attributes and individual characteristics). Models MNL3 and MNL4 are models with stated cutoffs, again without and with interactions.

Model MNL1 yields the expected signs on the coefficients. The attribute *sq* has a negative sign, indicating that respondents are willing to pay to avoid the status quo. Note that the status quo involves no costs to the respondent, but gives the minimal number of sustainable herds. The attribute *bid* has a negative coefficient, meaning respondents are less likely to choose an alternative with a higher cost. The attribute *herd* has a positive coefficient as expected, but it is not significant. This may be because the attribute *sq* has partially captured the preference for sustainable herds.

When interactions of attributes and individual characteristics are added in model MNL2, the attributes' coefficients do not change, except that *herd* and interaction terms are now significant. Looking at the interactions, older respondents are less likely to prefer more caribou herds. Those living longer in Alberta prefer more herds, however they are more sensitive to cost. Finally those who work full-time are less sensitive to cost. These results are stable across models.

Models MNL3 and MNL4 are similar to MNL1 and MNL2, but now violations of self-reported cutoffs are included as exogenous variables. Specifically, violations of lower herd cutoffs, and violations of upper bid cutoffs are included. Coefficients of violations are negative as expected, implying that alternatives with violations are penalized in terms of utility.

When violations are included, the signs of *herd* and *bid* change. The attribute *herd* now has a negative coefficient, implying that once the alternative reaches the minimum required number of herds (lower herd cutoff), additional herds will reduce utility. Note that below the cutoff point, an additional herd will have positive marginal utility because it reduces the herd cutoff violation. Given that the average herd cutoff is 9, as presented in Table 3.6, the results of models MNL3 and MNL4 imply that respondents have a marginal utility for an additional herd up to approximately 9 herds, then has a negative marginal utility for *herd*. Similarly for *bid*, models MNL3 and MNL4 indicate that respondents are willing to pay more for a given number of caribou herds, but become less willing to pay once the cost reaches the maximum acceptable cost (upper bid cutoff).

Table 3.4: MNL models

MODEL	**Simple MNL model (MNL1)**	**MNL model with interactions (MNL2)**	**Simple MNL model with stated cutoffs (MNL3)**	**MNL model with interactions with stated cutoffs (MNL4)**
		ATTRIBUTES		
ASC – Status quo	-0.588† (0.145)	-0.578† (0.148)	-0.305* (0.161)	-0.318ϒ (0.163)
Herd	0.027 (0.018)	0.101ϒ (0.042)	-0.133† (0.028)	-0.068 (0.051)
Bid ($10)	-0.027† (0.003)	-0.023† (0.007)	0.012ϒ (0.005)	0.019ϒ (0.009)
		INTERACTIONS		
Herd x Age		-0.004† (0.001)		-0.003† (0.001)
Herd x Years living in Alberta		0.003† (0.001)		0.003† (0.001)
Bid x Years living in Alberta		-0.0005† (0.0002)		-0.0005ϒ (0.0002)
Bid x full-time work		0.019† (0.005)		0.0012ϒ (0.0054)
		PENALTY ON CUTOFF VIOLATIONS		
Herd			-0.273† (0.033)	-0.260† (0.033)
Bid (in $10)			-0.064† (0.006)	-0.062† (0.007)
Log-likelihood	-601.04	-580.00	-511.44	-500.81
Rho-square	0.093	0.125	0.228	0.244

*Note: † Significant at 1% level. ϒ Significant at 5% level. * Significant at 10%. Standard errors are in parentheses.*

Table 3.5 presents the estimation results of the proposed model. In these models cutoffs are estimated endogenously from the choice observations. Models CEL1 and

CEL2 estimate cutoffs as constants, implying aggregate cutoffs for the entire sample. Model CEL2 includes interactions. Models CEL3 and CEL4 are similar but estimating cutoffs as functions of individual characteristics. Note that in these models cutoff violations are calculated from the estimated cutoff functions and attribute levels. The last column of Table 3.5 presents the direct Poisson regression of self-reported cutoffs on individual characteristics, allowing a comparison with the cutoff functions estimated from the proposed model as in models CEL2 and CEL4.

In terms of log-likelihood values[3], stated cutoff models show significant improvements compared to models MNL1 and MNL2. This shows that self-reported cutoffs make a remarkable contribution to explaining the choice behaviour. Models with endogenous cutoffs also improve the log-likelihood value compared to MNL1 and MNL2, but not as significant as stated cutoff models. The estimated cutoffs contribute to log-likelihood value, but not as much as the self-reported cutoffs. This may be because the self-reported cutoffs are not well explained by individual characteristics we have.

Coefficients of cutoff violations are somewhat different from those of the stated cutoff models. Models CEL1 and CEL2 have coefficients of cutoff violations that are very different, although they are negative. The bid cutoff violations are insignificant. In models CEL3 and CEL4, the estimated coefficients of herd cutoff violations are very close to model MNL3 and MNL4. However for bid cutoff violations, the estimated coefficients are only half as large as those of model MNL3 and MNL4.

[3] Both likelihood ratio tests of model MNL3 against MNL1, and MNL4 against MNL2 yield p-values smaller than 0.001.

Table 3.5: Estimation results of endogenous cutoff model

MODEL	CEL1	CEL2	CEL3	CEL4	Poisson [(b)]
UTILITY FUNCTION - ATTRIBUTES					
ASC – Status quo	-0.162 (0.202)	-0.112 (0.216)	0.13 (0.236)	0.044 (0.214)	
Herd	-0.003 (0.031)	0.064 (0.049)	0.014 (0.019)	0.082* (0.045)	
Bid ($10)	-0.024* (0.013)	-0.019 (0.02)	-0.014ϒ (0.007)	-0.006 (0.009)	
UTILITY FUNCTION - INTERACTIONS					
Herd x Age		-0.004† (0.001)		-0.004† (0.001)	
Herd x Years living in Alberta		0.003† (0.001)		0.003† (0.001)	
Bid x Years living in Alberta		-0.001† (0.000)		-0.001† (0.000)	
Bid x full-time work		0.02† (0.004)		0.008 (0.006)	
UTILITY FUNCTION - PENALTY ON CUTOFF VIOLATIONS					
Herd	-0.143ϒ (0.063)	-0.159† (0.058)	-0.356† (0.119)	-0.289† (0.081)	
Bid (in $10)	-0.006 (0.013)	-0.007 (0.02)	-0.023† (0.007)	-0.017† (0.007)	
HERD CUTOFF FUNCTION					
Constant	1.881† (0.139)	1.908† (0.117)	1.099† (0.002)	1.116† (0.19)	1.959† (0.055)
Fulltime work			0.363† (0.095)	0.318ϒ (0.131)	0.090* (0.050)
Watch TV programs about animals			-0.044 (0.075)	0.021 (0.088)	0.046 (0.052)
Hunter			0.217ϒ (0.099)	0.153 (0.126)	0.133 (0.082)
Urban			0.290† (0.091)	0.337† (0.132)	0.161† (0.055)
BID CUTOFF FUNCTION					
Constant	2.015† (0.000)	2.015† (0.001)	-0.762 (0.576)	-0.619† (0.007)	-0.407† (0.169)
Watch TV programs about animal			2.708† (0.541)	2.079† (0.008)	0.954† (0.111)
Income			0.208† (0.005)	0.277† (0.000)	0.063† (0.012)
Urban			-1.386† (0.042)	-2.079† (0.01)	-0.297† (0.113)
Log-likelihood	-597.19	-575.70	-579.35	-567.10	
Rho-square	0.099	0.131	0.126	0.144	
Run time [(a)]	2	2	6	4	

*Note: † Significant at 1% level. ϒ Significant at 5% level. * Significant at 10%. [(a)] in minutes, running on a computer with a six-core processor at 3.47GHz. [(b)] Direct Poisson regressions (right-censored for the case of herd cutoff) of stated cutoffs on individual characteristics.*

Coefficients of attributes in endogenous cutoff models have the expected signs, however many of them are not significant at a 10% level. In models CEL3 and CEL4, the status quo has insignificant coefficients. Only model CEL4 has the expected positive coefficient for herd. The coefficients of bid has a negative sign as expected, however in CEL2 and CEL4 they are not significant, possibly because the effects are already captured by the bid cutoff violations and interaction terms. Coefficients of interactions terms are close to those of models MNL3 and MNL4.

Some of the estimated cutoff functions from models CEL3 and CEL4 are very different from the Poisson regressions of self-reported cutoffs on individual characteristics (last column of Table 3.5), however in most cases they are consistent in terms of signs. In the bid cutoff function, the coefficient of income is positive, indicating that respondents with higher income have a higher cutoff. In other words, the maximum level of cost that is still acceptable is higher for higher income respondents. Variable *tvwatch*, has a positive coefficient, implying that those who frequently watch TV programs about animals have higher bid cutoff. Urban respondents have lower bid cutoffs.

Although the estimated herd cutoff functions show differences compared to the Poisson regression, their estimates are consistent in terms of signs with the Poisson regression. Full-time workers require more caribou herds in the proposed model and in the Poisson regression. In all models, urban respondents appear to have higher herd cutoffs. Those who watch TV programs about animals show no difference in herd cutoff. The variable *hunter*, indicating that the respondent went hunting in the last 12 months, is significant only in model CEL3.

In summary, some coefficients of the estimated cutoff functions are similar to the Poisson regression functions of self-reported bid cutoffs. In most cases they are consistent in terms of sign. Table 3.6 presents the average cutoffs, including those from self-reported data and estimated from our proposed model. On average, a respondent requires 9 self-sustaining caribou herds and is willing to pay no more than $140 per year per household. Models CEL1 and CEL2 predict lower herd as well as bid cutoffs. Estimates from models CEL3 and CEL4 result in average bid cutoffs of $124 and $170, which are not that far from the self-reported bid cutoffs. However for herd cutoffs, the average estimate is less than 5 caribou herds, which is half of the stated herd cutoff. This is possibly because respondents set different cutoffs when making choices.

Table 3.6: Comparison of self-reported and predicted cutoffs[4]

Mean of	Stated cutoffs	CEL1	CEL2	CEL3	CEL4
Herd cutoff (herds)	9.10	6.50	6.77	4.55	4.80
Bid cutoff ($)	140	75	75	124	170

3.6 WELFARE MEASURES

This section explains the procedure of calculating welfare measures corresponding to woodland caribou conservation strategies. We calculate the willingness to pay (WTP) for three different strategies that offer 4, 8 and 12 self-sustaining herds. We start with the utility function

[4] We also explore the model with different specification. One is with only herd cutoff (see Appendix 3.1). Another specification is with only herd cutoff, but with a different way of categorizing (Appendix 3.2). The estimated coefficients and cutoff values are close to the full models presented in Table 3.5.

$$V_j = \alpha sq + \beta M + \vartheta M Z^M + \eta H_j + \mu H_j Z^H + w\hat{\chi}_j + v\hat{\kappa}_j$$

where sq is the status quo, M is income, H is herd, Z^M and Z^H are the vectors of demographics interacted with M and H, and $\hat{\chi}_j$ is the lower herd cutoff and $\hat{\kappa}_j$ upper bid cutoff defined by (3.3a) and (3.3b). The willingness to pay t that equates utilities of the two alternatives 0 (base case) and 1 (improved case or additional self sustaining herds) is defined by

$$\alpha + \beta M + \vartheta M Z^M + \eta H_0 + \mu H_0 Z^H + w\hat{\chi}_0 + v\hat{\kappa}_0 =$$

$$= \beta\left(M - t\right) + \vartheta\left(M - t\right) Z^M + \eta H_1 + \mu H_1 Z^H + w\hat{\chi}_1 + v\hat{\kappa}_1$$

Note that $\hat{\kappa}_0 = 0$ because there is no bid violation at the status quo. The utility difference caused by an increase in the number of herds is $-\alpha + \left(H_1 - H_0\right)\left(\eta + \mu Z^H\right) + w\left(\hat{\chi}_1 - \hat{\chi}_0\right)$. This should be divided by the marginal utility of money to obtain WTP. However, in models with bid cutoffs, the marginal utility of money changes at the bid cutoff point. Up to the cutoff point, the marginal utility of money $\beta + \vartheta Z^M$ applies. Beyond the cutoff point, $\beta + \vartheta Z^M - v$ applies. As a result, WTP is

$$t = \frac{-\alpha + \left(H_1 - H_0\right)\left(\eta + \mu Z^H\right) + w\left(\hat{\chi}_1 - \hat{\chi}_0\right)}{\beta + \vartheta Z^M} \qquad \text{if } t \le \theta_i^U$$

$$t = \theta_i^U + \frac{-\alpha + \left(H_1 - H_0\right)\left(\eta + \mu Z^H\right) + w\left(\hat{\chi}_1 - \hat{\chi}_0\right) - \theta_i^U\left(\beta + \vartheta Z^M\right)}{\beta + \vartheta Z^M - v} \quad \text{if } t > \theta_i^U$$

where θ_i^U is the upper bid cutoff of individual i.

Table 3.7 presents the welfare measures from MNL models and endogenous cutoff models. Columns 2, 3 and 4 present the WTP measures for the three management strategies calculated from different models. Measures are $/year/family. Standard deviations are calculated using the Krinsky-Robb method with 1,000 draws assuming normal distributions. Only marginal utility parameters (α, β, η, μ, w, v) are drawn. Parameters of the cutoff functions are not.

Table 3.7 shows that WTP is approximately $200/year for the management strategy that provides 4 herds, and $250-300/year for strategies that provide 8 and 12 herds. Model MNL1 generates WTP estimates that increase with the number of herds. Model MNL2 results in WTP estimates of about $230-240/year for all strategies.

Table 3.7: Willingness To Pay for woodland caribou management strategies

Number of self-sustaining herds	**4 herds**	**8 herds**	**12 herds**
Model MNL1	237.78 (62.97)	277.78 (78.09)	317.78 (99.15)
Model MNL2	266.83 (200.73)	255.64 (290.03)	244.45 (423.76)
Model MNL3	222.90 (47.25)	278.95 (69.22)	277.23 (88.17)
Model MNL4	145.40 (60.72)	181.11 (103.84)	174.82 (146.71)
Model CEL1	161.72 (522.44)	279.31 (877.49)	274.91 (895.02)
Model CEL2	160.37 (183.65)	292.81 (375.69)	276.62 (434.56)
Model CEL3	201.19 (178.37)	286.08 (190.30)	302.83 (194.54)
Model CEL4	188.77 (141.13)	278.40 (226.93)	274.16 (295.16)

Note: Without management, the number of self-sustaining herds after 50 years is expected to be 2 herds. Measures are in $/year/family. Standard deviations are in parentheses.

WTPs from models with self-reported and endogenous cutoffs exhibit a common pattern. They start with WTPs for 4 herds lower than those from MNL1 and MNL2. However the WTPs from these models increase sharply when the number of herds reaches 8 and at this point the WTPs are approximately equal to those from MNL1 and MNL2. WTPs for a 12-herd management strategy are slightly lower than those for an 8-herd strategy in these models. This reflects the fact that the overall marginal utility of herds is slightly negative in all models with cutoffs, except in model CEL3. The main contribution for a positive WTP for a 4-herd strategy is avoiding the status quo and the reduction of the herd cutoff violation. From 4 herds to 8 herds, WTPs increase remarkably because of the elimination of the herd cutoff violation. However, moving from 8 to 12 herds does not improve welfare because in most cases, the herd cutoffs are around 4-7 herds in the endogenous cutoff models or 10 in self-reported cutoff models, and thus the herd increase from 8 to 12 does not reduce, or just slightly reduces herd cutoff violations.

3.7 CONCLUSIONS

This paper constructs an analytical model to estimate cutoffs endogenously. In the proposed model, the cutoff function is assumed to have a Poisson distributed error term that is appropriate for our data and allows for a tractable model. When incorporating the cutoff function in the choice model, this error term is added to the conventional Gumbel error. We estimate the model via maximum likelihood, taking into account the two error terms. Our approach provides a tractable way to estimate non-compensatory preferences without relying on stated cutoffs. It is relevant to cases where compensatory preferences may not be appropriate, and where analysts wish to estimate cutoffs without information from self-reported cutoffs. Our model depends on there being sufficient explanatory power in observed exogenous variables, such as individual characteristics, in the modelled cutoff values.

We tested the proposed model with synthetic data and found that estimates of the model are very close to the true parameters. We then applied the model to a real data set, which are from a survey in Alberta about choices of caribou conservation options. The results suggest that our model shows some improvement over basic MNL models, but is not as good in terms of in-sample prediction as the MNL models with self-reported cutoffs. Some of the estimated coefficients of cutoff functions from the proposed model are close to the Poisson regressions of self-reported cutoffs on corresponding individual characteristics, and most are consistent in signs with Poisson regressions. Because models with cutoffs outperform those without cutoffs, we suggest that cutoffs be considered when analyzing choice behavior. In our case study, the model with stated cutoffs is statistically better than the proposed endogenous cutoff model. However, our proposed model is helpful for the case where cutoffs are important, but stated cutoff information is unavailable. As respondents may be unable to report cutoffs accurately (Nisbett and Wilson, 1977) or may adapt their cutoff levels to the choice environment (Payne *et al*. 1988), or may be willing to adjust their cutoff when evaluating a particular alternative (Klein and Bither, 1987, Huber and Klein, 1991, Swait, 2001), a cutoff model that does not rely on stated cutoff such as our proposed model may be more desirable than a stated cutoff model.

The bid cutoffs estimated from our proposed models are close to the self-reported cutoff, however herd cutoffs estimated from our model are lower than the self-reported herd cutoff. This is possible because, as mentioned above, when facing the choice, respondents adjust their cutoffs to suit the choice context. Respondents appear to require more caribou herds in response to the herd cutoff question, but they lower their requirement when facing the choice with information about the associated cost.

As woodland caribou is listed as “Threatened”, it is required by the *Species At Risk Act* in Canada that an action plan for recovery must be created together with estimated socio-economic costs and benefits. To do cost-benefit analysis, our estimated WTP for woodland caribou conservation strategies can be compared to the opportunity costs of conservation adopted from Schneider *et al*. (2010), which result from reduced activities in the forestry, oil and gas industries, reduced revenue to the government, and the direct costs of wolf control and reclamation. Harper (2012) examines costs and benefits from a relatively simple MNL models and estimates that the optimal level of conservation is between 4 to 11 herds. Our analysis of the stated cutoffs shows that additional herds are not desirable when the number of herds is more than 9. Results from our proposed models suggest that the minimum acceptable number of herds is from 5 to 7 and additional herds are not always desirable beyond these levels. While our results are within the range suggested by Harper (2012) more information is provided from our models and the cutoff estimates.

Although our proposed model works well with the synthetic data in terms of recovering the true parameters, it is more challenging to estimate using the real data. The specification of the cutoff function seems to be quite important. There are two aspects that should be considered in future development of our proposed model. First, the log-likelihood function likely has multiple local optima. By the nature of the cutoff violations the utility function is kinked at the cutoff points. As a result, the model has multiple solutions. An approximation of the utility function with cutoffs as in Martinez *et al*. (2009) should be investigated as an alternative. Second, the Poisson distribution may not be a good approximation for the cutoffs that are continuous. Other distributions, particularly continuous probability distributions which are appropriate for continuous attributes, should be investigated. In addition the proposed model is limited to two alternative choices and thus there is a need for a model that works for multiple alternative choices. In a broader context, there is a linkage between cutoff models of the type we investigate and models of choice set formation. The relationship between these classes of models deserves further analysis.

REFERENCES

Bettman J.R. and C.W. Park. 1980. Effects of prior knowledge and experience and phase of the choice process on consumer decision processes: A protocol analysis. *Journal of Consumer Research* 7(3): 234-248.

Cascetta, E., A. Papola, 2001. Random utility models with implicit availability/perception of choice alternatives for the simulation of travel demand. *Transportation Research Part C* 9 (4): 249–263.

Coombs, C.H. 1964. A Theory of Data. NY: John Willey.

Dawes, R.M. 1964. Social selection based on multidimensional criteria. *Journal of Abnormal and Social Psychology* 68(1): 104-109.

Ding, Y. 2010. Three Essays on Consumer Behavior and Food Risks. *Dissertation*. Department of Rural Economy. University of Alberta.

Einhorn, H. 1970. The use of nonlinear, noncompensatory models in decision-making. *Psychological Bulletin* 73(3): 221-230.

Einhorn, H.J., D.N. Kleinmuntz and B. Kleinmuntz. 1979. Linear regression and process-tracing models of judgement. *Psychological Review* 86(5): 465-485.

Elrod, T., R.D. Johnson and J. White. 2004. A new integrated model of noncompensatory and compensatory decision strategies. *Organizational Behavior and Human Decision Processes* 95: 1-19.

Gensch, D.H. and J.A. Svetska. 1984. A Maximum Likelihood Hierarchical Disaggregate Model for Predicting Choices of Individuals. *Journal of Mathematical Psychology* 28: 160-178.

Grether, D. And L. Wilde. 1984. An analysis of conjunctive choice: Theory and experiments. *Journal of Consumer Research* 10: 373-385.

Harper, D. 2012. Analyzing the Economic Benefit of Woodland Caribou Conservation in Alberta. *M.Sc. Thesis*. Department of Rural Economy. University of Alberta.

Klein, N.M. 1983. Utility and Decision Strategies: A second look at the rational decision maker. *Organizational Behavior and Human Performance* 31: 1-25.

Klein, N. M. and S. W. Bither. 1987. An Investigation of Utility-Directed Cutoff Selection. *Journal of Consumer Research* 14(2): 240-256.

Huber, J. and N. M. Klein. 1991. Adapting Cutoffs to the Choice Environment: The Effects of Attribute Correlation and Reliability. *Journal of Consumer Research* 18(3): 346-357.

Lussier D.A. and R.W. Olshavsky. 1979. Task complexity and contingent processing in brand choice. *Journal of Consumer Research* 6(2): 154-165.

Lynch, J.G Jr. 1983. Looking for confirming evidence: The case of the elusive conjunctive consumer decision process. *Center for Consumer Research Working paper #31*. University of Florida, Gainesville.

Martinez, F., F. Aguila and R. Hurtubia. 2009. The constrained multinomial logit: A semi-compensatory choice model. *Transportation Research Part B* 43: 365-377.

Nisbett, R.E. and T.D. Wilson. 1977. Telling more than we can know: Verbal reports on mental process. Psychological Review 84(3): 231-259.

Payne, J.W. 1976. Task complexity and contingent processing in decision making: An information search and protocol analysis. *Organizational Behavior and Human Performance* 16: 366-387.

Payne, J.W., J.R. Bettman and E.J. Johnson. 1988. Adaptive strategy selection in decision making. *Journal of Experimental Psychology: Learning, Memory and Cognition* 14(3): 534-552.

Schneider, R.R., G. Hauer, W. L. Adamowicz and S. Boutin. 2010. Triage for conserving populations of threatened species: The case of woodland caribou in Alberta. *Biological Conservation* 143: 1603-1611.

Swait, J. 2001. A non-compensatory choice model incorporating attribute cutoffs. Transportation *Research Part B* 35: 903-928.

Tversky, A. 1972. Elimination by aspects: A theory of choice. *Psychological Review* 79(4): 281-299.

Wright, P.L. 1975. Consumer choice strategies: Simplifying vs. Optimizing. *Journal of Marketing Research* 12: 60-67.

CHAPTER 4: PROBABILITY WEIGHTING: THE EFFECT OF INCENTIVE, MOODS AND HETEROGENEITY

With the axiomatization of the expected utility hypothesis by von Neumann and Morgenstern (1944), economists have applied expected utility theory (EUT) to a wide range of economic issues, including the theory of economic behavior under risk and uncertainty. EUT has been the underlying theory for eliciting measures of risk aversion (RA). The concept of risk aversion was constructed by Friedman and Savage (1948), noting that when facing a choice between comparable outcomes, decision makers tend to choose the less risky one. The concept is then related to the curvature of the utility function. Pratt (1964) and Arrow (1965) used this curvature to measure the degrees of RA, which are now well-known as the Arrow-Pratt absolute and relative RA.

Measuring Arrow-Pratt RA empirically has attracted the attention of many psychologists and economists. Attempts to measure utility functions and RA are reviewed in Luce and Suppes (1965), Hershey, Kunreuther and Schoemaker (1982) and more recently Harrison and Rutström (2008). The methods of measurement include interview techniques and laboratory experiments. Several utility function elicitation procedures have been developed. RA measures are then inferred or estimated based on EUT.

However, there is considerable evidence that actual choice behavior is inconsistent with EUT (Schoemaker, 1982 and Camerer, 1995). As a result, economists have been searching for non-expected utility theories as alternatives for EUT (Starmer, 2000). Among the alternatives are subjective expected utility (SEU) theory (Savage, 1954) rank dependent expected utility theory (Quiggin, 1981 and Schmeidler, 1989), and prospect theory (Kahneman and Tversky, 1979 and Tversky and Kahneman, 1992). These theories allow subjects to subjectively weight objective probabilities and thus require a weighting function that transforms objective probabilities to subjective probabilities or decision weights. This probability transformation addresses a common criticism of empirical research measuring RA, which is the confounding of utility and probability weighting. Because expected utility is the product of utility and probability, the existence of probability weighting may produce inaccurate estimates of RA using EUT.

There is a large body of evidence suggesting that subjective probabilities (SPs) deviate from objective probabilities (Luce and Suppes, 1965). The existence of SPs make the task of eliciting RA measures more difficult because of the confounding of utility and SPs. Early attempts to deal with this problem include trying to find a lottery where SP is known (Davidson, Suppes and Siegel 1957, Edwards, 1955) and doing experiments to identify the SP function using an assumed or constructed utility function (Preston and Baratta 1948, Edwards 1955, Mosteller and Nogee 1951, Davidson, Suppes and Siegel 1957, Toda 1951, 1958).

Methods have been developed to elicit the utility and probability weighting functions. The conventional method is the certainty equivalent (CE) method, which asks subjects for the CE of a lottery (Luce and Suppes, 1965). Assuming functional forms for the utility and weighting function, and by equating the utility of CE and the weighted utility of the lottery outcomes, parameters of those functions can be estimated using a non-linear least squares method. In the probability equivalent (PE) method, a subject is asked for the probability that makes him indifferent between a certain amount and a lottery. The PE method can elicit utility functions without knowing the probability weighting function. Other methods include the gamble-tradeoff method (Wakker and Deneffe, 1996), non-parametric estimation (Bleichrodt and Pinto, 2000, Abdellaoui, 2000, and

Gonzalez and Wu, 1999), and maximum-likelihood estimation of choice models. Maximum likelihood estimation of choice models is widely used to analyze choice behavior under risk and uncertainty using non-EUT models (for example Camerer and Ho 1994, Hey and Orme 1994, and more recently Harrison and Rutström 2008, Harrison, Humphrey and Verschoor 2009).

A substantial amount of individual heterogeneity in decisions under risk has been found in empirical analyses (Hey and Orme 1994, Harrison and Rutström 2008, and Wilcox 2011). Many authors attribute this to cognition or processing errors, but it may be unobserved heterogeneity in risk preferences. Although many authors have estimated the utility function and the weighting functions as functions of individual characteristics to capture observed heterogeneity, little has been done to capture unobserved individual heterogeneity. Andersen, Harrison, Hole, Lau and Rutström (2012) applied a mixed logit model to allow for heterogeneity in risk aversion. However the heterogeneity may be in the subjective weighting of probabilities due to "sensitivity to emotional incidence" (Fehr-Duda *et al*. 2011). Because of the confounding of probability weightings and utility, risk seeking/avoiding can arise from the probability weighting and/or the curvature of the utility function.

This study investigates the possible deviation of subjective perceptions from objective probabilities, and the possible factors that affect subjective perceptions. In this study we use a mixed non-linear logit model to estimate parameters of the weighting and utility functions under a non-EUT model. Random parameters are included to allow for heterogeneity in utility functions as well as probability weighting functions. We illustrate the estimation method using data from Harrison, Johnson, McInnes and Rutström (2005). The data are collected using the experimental design adapted from Holt and

Laury (2002) , in which subjects are asked to make sequences of choices between two prospects. Harrison *et al*. (2005) re-do the experiments to point out the order effect, that is, subjects who attended a previous game session tend to be more risk averse in the next round. Because winning a lower or higher payoff in the previous session may have certain psychological impacts on the subjects, it may affect the attitude towards risk through the subjective weighting of probabilities. Therefore, ignoring this psychological effect may result in incorrect estimation of risk aversion. In this paper we also attempt to control for the psychological effect that previous experiment has on probability weighting.

We estimate a scale parameter as a function of individual characteristics. This will allow for heteroskedasticity in the discrete choice model. The scale parameter is known to be inversely related to error variance (Ben-Akiva and Lerman, 1985). Estimating the scale function will allow for different error variances among different groups of agents, which, together with the random components in the mixed logit model, further captures the heterogeneity of choice under risk found in the literature.

4.1 EUT AND RA MEASUREMENT METHODS

The expected utility hypothesis of von Neumann and Morgenstern (1944) states that expected utility of a lottery can be written as $EU = \sum_k p_k u(x_k)$ where $u(x_k)$ is the utility and p_k is the corresponding probability of the occurrence of outcome x_k. Assuming that agents maximize expected utility, measures of RA can be identified by the curvature of the utility function.

Pratt (1964) has defined and Arrow (1965) extended the measure of RA using the curvature of utility function. Let W stand for the final wealth, consisting of initial wealth w and a new prospect m, then $U(W)=U(w+m)$. The absolute level of risk aversion is defined as $R=-\frac{U''(W)}{U'(W)}$ and relative RA is $r=WR=-W\frac{U''(W)}{U'(W)}$. In addition, Menzes and Hanson (1970) and Zeckhauser and Keeler (1970) define partial relative RA as $r_p=mR=-m\frac{U''(W)}{U'(W)}$.

Several RA elicitation methods have been developed, including CE elicitation, multiple price list, random lottery pairs, ordered lottery selection and gamble trade-off method (see Harrison and Rutström, 2008 for a review). CE elicitation is the conventional method which asks subjects to make a sequence of choices to elicit the CE of a lottery. In the CE method, the CE has to be identified for each lottery, usually by varying the certain amount until the analyst can reveal the amount that makes the subject indifferent between that certain amount and the lottery. If one can find the point at which the subject is indifferent between the two, that is

$$u(x_0)=pu(x_1)+(1-p)u(x_2) \qquad (4.1)$$

and fix the utility at x_0 (CE) and x_1, the utility at x_2 can be found. Using this method, the utility function can be constructed and thus RA can be measured.

The CE method is prone to several potential biases in cases where subjects have preference for, or aversion to, gambling. An alternative method, which is referred to as the Ramsey method, was developed by Davidson, Suppes and Siegel (1957) to avoid this problem. In this method, the utility function is constructed based on choices over pairs of lotteries with same probabilities $(x_1, p; x_2)$ and $(x_3, p; x_4)$. Then

$$pu(x_1)+(1-p)u(x_2)=pu(x_3)+(1-p)u(x_4)$$

which can help reveal the utility function.

The probability equivalent (PE) method is similar to CE method, but the amounts are fixed and the analyst asks for the probability that makes subjects indifferent between the certain amount and the lottery. Again the utility function and thus RA measures can be obtained by using equality (4.1).

The multiple price list method asks subjects to make a set of choices over binary lotteries (for example Holt and Laury, 2002). The random lottery selection method asks subjects to make choice over a set of ordered lotteries (for example, Binswanger, 1980 and Eckel and Grossman, 2008). The gamble trade-off design asks subjects to make choices over a pair of lotteries in several stages to elicit the utility of lotteries without any assumptions about probability weighting (Wakker and Deneffe, 1996).

The two popular methods of RA estimation are inferring bounds from observed choices and maximum likelihood estimation of a structural model. Upper and lower bounds of RA can be inferred from choices by assuming a one-parameter utility function, assuming subjects maximize expected utility (see for example Binswanger, 1980, Holt and Laury 2002 and Harrison *et al*. 2005). The method of maximum likelihood estimation is proposed by Camerer and Ho (1994) and Hey and Orme (1994). This method requires a particular set of assumptions on the utility function. Its application can be found in Harrison and Rutström (2008). Andersen *et al*. (2012) estimate the parameters of the utility function using a mixed logit model, in which random parameters are introduced to allow for heterogeneity among subjects in terms of RA.

4.2 NON-EUT WITH DECISION WEIGHTS

Estimation of RA based on EUT is inaccurate if subjects weight objective probabilities non-linearly. There may be a psychological transformation of objective probabilities, which results in personal or subjective probabilities. The idea of SP was first discussed by Savage (1954). The simplest forms of SEU model are discussed by Edwards (1962) and Handa (1977). In the SEU model agents are assumed to choose the course of action that maximizes their subjectively weighted expected utility

$$V(q) = \sum_k w_k u(x_k) \qquad (4.2)$$

The subjective probability (SP) $w_k = \pi(p_k)$ can be lower or higher than the objective probability, which implies that agents may overweight or underweight the objective probability. In the case where full information is available, subjective and objective probabilities are identical and the SEU model reduces to the EU model.

The utility function and probability weighting function $w_k = \pi(p_k)$ are the two components of prospect theory (Kahneman and Tversky, 1979). The utility function is defined separately for the gain and loss domain, and the probability weighting function transforms objective probabilities to subjective probabilities. The overall value of a lottery in prospect theory (PT) shares the same formulation as in (4.2). In PT, risk aversion and risk seeking are determined by the weighting and the value function jointly.[5]

[5] Note in this paper, we consider the attitude toward risk to be determined solely by the utility function and the subjective probability distortion by the weighting function.

One obvious shortcoming of a formulation as in (4.2) is that it allows for subcertainty (sum of all probabilities is lower than unity) and may violate basic principles such as monotonicity and stochastic dominance (Fishburn, 1978). For example, because the sum of all outcome probabilities can be lower than 1, there could be cases that a certain amount x is preferred to a lottery $(x, p; x+\varepsilon, 1-p)$ where $\varepsilon > 0$. In the theory of rank dependence expected utility (Quiggin, 1981 and Schmeidler, 1989), the weights for outcomes $k = 1, \ldots, n-1$ are replaced by

$$w_k = \pi(p_k + \ldots + p_n) - \pi(p_{k+1} + \ldots + p_n) \qquad \text{and} \qquad w_n = \pi(p_n)$$

and the sum of all outcome probabilities should be 1. Tversky and Kahneman (1992) adopted this formulation for their PT, which is called cumulative prospect theory (CPT).

Theories with decision weights allow for SPs or weights that are different from objective probabilities and may produce a more accurate measure of RA. However they require estimating the weighting function together with the utility/value function. Several methods have been applied to estimate the decision weights and their deviation from objective probabilities in non-EUT theories.

Several authors have assumed or constructed utility functions using axioms of SP, and used that utility function to measure SP. These authors include Preston and Baratta (1948), Edwards (1955), Mosteller and Nogee (1951), Toda (1951, 1958) and Davidson, Suppes and Siegel (1957).

The gamble-tradeoff method has been proposed by Wakker and Deneffe (1996) to elicit the utility function without knowing the weighting function. In this method, the levels of X and Y have to be identified such that subjects are indifferent between two pairs of lotteries $(X, p; m) \sim (x, p; M)$ and $(Y, p; m) \sim (y, p; M)$, each lottery offers an outcome (X, x, Y, y) with probability p and a fixed amount (m or M), where p, m, x and M are fixed.

The two indifferences imply

$$p\left[u(X)-u(x)\right]=(1-p)\left[u(M)-u(m)\right]$$

and $$p\left[u(Y)-u(y)\right]=(1-p)\left[u(M)-u(m)\right]$$

The two equations result in $u(X)-u(x)=u(Y)-u(y)$. This indifference helps reveal the utility function without knowing the SPs.

Two major methods of estimating weighting and utility functions are non-parametric and parametric methods. Non-parametric estimation methods usually use a sequence of lottery choices to elicit the utility function and then the weighting function. This estimation method is mainly based on the gamble-tradeoff. For example, once the utility function is constructed (for instance, using the gamble-tradeoff method), the SP function can be identified using CE data. If $x_3 \sim (x_1, p; x_2)$, then

$$w(p)u(x_1)+\left[1-w(p)\right]u(x_2)=u(x_3)$$

So $$w(p)=\frac{u(x_3)-u(x_2)}{u(x_1)-u(x_2)}$$

The method is extended by Fennema and van Ansen (1999) for both loss and gain domains. Abdellaoui (2000) elicits the weighting function using constructed utility. More recent developments on this method can be found in Bleichrodt and Pinto (2000), and Abdellaoui, Bleichrodt and Paraschiv (2007).

Parametric estimation of the weighting and utility functions is usually conducted using non-linear least squares methods for the CE equation or maximum likelihood estimation of a structural model. Using CE data, the weighting and value functions can be estimated using nonlinear least squares

$$u(CE) = \sum_k w_k u(x_k) + \varepsilon \qquad \text{or} \qquad CE = u^{-1}\left(\sum_k w_k u(x_k)\right) + e \qquad (4.3)$$

where $w_k = \pi(p_k)$ for PT or defined by equation (4.2) for CPT. The equation can be estimated using individual data or aggregate data by assuming functional forms for the weighting and utility functions. See, for example, Gonzalez and Wu (1999), Fehr-Duda *et al*. (2011), and Abdellaoui (2000).

Maximum likelihood estimation methods do not require CE data and can be applied to any type of choice data. The method has been widely adopted. Camerer and Ho (1994) and Hey and Orme (1994) construct a log-likelihood function to estimate the parameters of the value and weighting functions. Harrison and Rutström (2008) estimated the weighting function and utility function simultaneously assuming a structure of the weighting and value functions, using Holt and Laury (2005) data. Andersen, Fountain, Harrison and Rutström (2010) applied maximum likelihood methods to estimate the utility function and the probability weighting parameter under a rank dependent utility model. Bruhin *et al*. (2010) specified a log-likelihood function to estimate equation (3) allowing for different sources of heterogeneity among subjects. Harrison, Humphrey and Verschoor (2010) estimated utility function and probability weighting parameters as functions of individual characteristics using the prospect theory. This paper also employs a mixed model of EUT and PT in which choices under risk can be explained by either EUT or PT. Andersen, Fountain, Harrison, Hole, and Rutström (2011) estimated the distributional parameters of subjective beliefs of probabilities using a structural model.

This paper applies a mixed non-linear logit model to estimate the weighting and utility functions under non-EUT model. We analyze the heterogeneity of risk preference as well as probability weighting by introducing random parameters into the utility and probability weighting functions. We also examine for the psychological effect of previous experiment on probability weighting. We include a scale parameter to allow for different error variances among different groups of subjects. This scale parameter and the random components in the mixed logit model are expected to captures the heterogeneity of choice under risk found in the literature.

4.3 MODEL SPECIFICATION

In this paper we estimate the utility and probability weighting functions using a structural model. We use a constant relative risk aversion utility (CRRA) function $u(x)=\frac{x^{1-r}}{1-r}$. The relative RA is $R=r$, where $r>0$ indicates risk aversion, $r=0$ risk neutrality and $r<0$ risk loving. Higher values of r indicate higher degree of risk aversion.

For probability weighting, we use a two-parameter weighting function proposed by Goldstein and Einhorn (1987)

$$\pi_k(p)=\frac{\delta p^{\gamma+1}}{\delta p^{\gamma+1}+(1-p)^{\gamma+1}} \quad \text{where } \delta>0,\ \gamma>-1 \qquad (4.4)$$

The parameter γ determines whether there is an inflection point that defines the inverted S-shaped curve which is usually found under prospect theory, and δ

determines how much the SP deviates from the objective probability. If $\gamma > 0$, the subject under/over-weighs small/large probabilities and vice versa. If $\gamma = 0$, the subject always overweighs or underweighs probabilities depending on δ. If $\gamma = 0$ and $\delta = 1$, the probability weighting is always equal to objective probability. This weighting function was adopted by Gonzalez and Wu (1999), Tversky and Fox (1995) and its properties are discussed in depth in Lattimore *et al*. (1992).

In the data we analyze, each subject is asked to play ten games and each game has two options. Assuming a CRRA utility function, the expected utility of subject i from option t (t = A, B) of game j (j = 1, 2,…,10) is

$$EU_{ijt} = \sum_k p_{ijtk} u\left(x_{ijtk}\right) \text{ where } u\left(x\right) = \frac{x^{1-r}}{1-r} \quad (4.5)$$

where $k = l, h$ stands for low and high outcomes of the lottery.

The two popular alternative theories to EUT are rank dependent utility and CPT. We apply rank dependent utility model for this paper, however, because the data are in the gain domain only, the rank dependent model is identical to CPT.

The rank dependent utility (RDU) is now

$$RDU_{ijt} = \sum_k \pi_k\left(p_{ijtk}\right) u\left(x_{ijtk}\right) \quad (4.6)$$

The weighting function (4.4) is used to transform the probability of the lower outcome in each lottery

$$\pi_l\left(p_l\right) = \frac{\delta p_l^{\gamma+1}}{\delta p_l^{\gamma+1} + \left(1-p_l\right)^{\gamma+1}} \quad (4.7)$$

and the probability of the higher outcome is

$$\pi_h\left(p_h\right)=1-\pi_l\left(p_l\right) \tag{4.8}$$

Therefore, the rank dependent utility function can be rewritten as

$$RDU_{ijt}=\pi_l\left(p_l\right)u\left(x_{ijtl}\right)+\left[1-\pi_l\left(p_l\right)\right]u\left(x_{ijth}\right) \tag{4.9}$$

Using EU or RDU as the deterministic part of the utility function as defined in a standard multinomial logit (MNL) model, and with the choices of subjects in each game, the parameters of the utility and SP functions can be estimated using a nonlinear MNL model. The subjectively weighted expected utility of respondent i from option t can be separated into deterministic and random components

$$U_{it}=V_{it}+\varepsilon_{it} \tag{4.10}$$

where V_{it} is either expected utility as in (4.5) or RDU as in (4.6). The probability of respondent i choosing option t is

$$p_{it}=\frac{e^{\mu V_{it}}}{\sum_{m=A,B} e^{\mu V_{im}}} \tag{4.11}$$

where μ is the scale parameter, which is inversely related to the error variance. The scale parameter is modeled as a function of selective individual characteristics $\mu_i=e^{\mu z}$.

In order to estimate the effect of individual characteristics on risk aversion measures, the parameter r of the utility function is replaced by $r_i=r_0+\alpha z_i$, where z_i is a set of individual characteristics and α is a vector of corresponding coefficients. Note that α is the marginal effect of individual characteristics on the RA measure.

Individual characteristics are also introduced to the probability weighting function. We leave the parameter γ to be estimated without covariates, while modeling δ as a function of individual characteristics as δ determines the deviation of subjectively weighted probabilities from objective probabilities. Because of the restriction that $\delta > 0$, the exponential function $\delta_i = e^{\rho_0 + \rho z_i}$ is employed.

In order to allow for heterogeneity of RA and probability weighting, r_0 and ρ_0 are modeled as random parameters. The model therefore allows for different degrees of RA for different subjects (but not across games played by the same subject) and different levels of deviation from objective probability. Note that r_0 and ρ_0 are assumed to be normally distributed, or specifically $r_0 \sim N\left(\overline{r}_0, \sigma_r^2\right)$ and $\rho_0 \sim N\left(\overline{\rho}_0, \sigma_\rho^2\right)$.

Johnson and Tversky (1983), Wright and Bower (1992), and Fehr-Duda *et al*. (2011) found that risks are perceived higher if subjects are in a negative mood and vice versa. In Wright and Bower (1992), mood is controlled by letting subjects listen to music that is known to produce a particular effect, by providing a small reward and seeing happy/sad film/stories. For this paper, in order to control for the psychological effect of winning/losing in the previous game session, we include a dummy variable indicating whether the subject won (winning higher prize) or lost (winning lower prize) in the previous session. Following the previous studies, we hypothesize that winning a higher prize makes subjects more likely to overweight the probability of winning in the next round.

Five models are estimated. Model 1 is an EU model with single parameter utility function. Model 2 is the same as Model 1 but estimates the risk aversion parameter as a function of individual characteristics. Model 3 further introduces the scale function. Models 4 and 5 are rank dependent utility models. Model 4 has a normally distributed random component in the weighting function, but not in the utility function. Model 5 has random components in both functions. All models are estimated using BIOGEME (Bierlaire, 2003) with 500 pseudo random draws.

4.4 DATA

We estimate the models using data from Harrison *et al.* (2005).[6] This data set is based on the Holt and Laury type of elicitation method, collected from an experiment with two scales of payoffs: 1X, which is presented in Table 4.1, and 10X, which is ten times higher than 1X. There were 55 subjects attending the 10X sessions and 123 subjects attending 1X and then 10X sessions. The data were collected from experiments with students, all paid with real money, and include a set of demographics including race, gender, age, income and others variables. See Appendix 4 for the experiment script and questionnaire.

Table 4.1: Holt and Laury's risk aversion experiment – 1X scale

Game	Option A	Option B	E[A]-E[B]
1	0.1 of $2.0; 0.9 of $1.6	0.1 of $3.85; 0.9 of $0.1	1.17
2	0.2 of $2.0; 0.8 of $1.6	0.2 of $3.85; 0.8 of $0.1	0.83
3	0.3 of $2.0; 0.7 of $1.6	0.3 of $3.85; 0.7 of $0.1	0.50
4	0.4 of $2.0; 0.6 of $1.6	0.4 of $3.85; 0.6 of $0.1	0.16
5	0.5 of $2.0; 0.5 of $1.6	0.5 of $3.85; 0.5 of $0.1	-0.18
6	0.6 of $2.0; 0.4 of $1.6	0.6 of $3.85; 0.4 of $0.1	-0.51
7	0.7 of $2.0; 0.3 of $1.6	0.7 of $3.85; 0.3 of $0.1	-0.85
8	0.8 of $2.0; 0.2 of $1.6	0.8 of $3.85; 0.2 of $0.1	-1.18
9	0.9 of $2.0; 0.1 of $1.6	0.9 of $3.85; 0.1 of $0.1	-1.52
10	1.0 of $2.0; 0.0 of $1.6	1.0 of $3.85; 0.0 of $0.1	-1.85

[6] With authors' permission.

The standard HL game setting is presented in Table 4.1. Each respondent is asked to play 10 games. Each game involves a choice between the safe lottery A $\left(x_{Al}, p; x_{Ah}\right)$ and the risky lottery B $\left(x_{Bl}, p; x_{Bh}\right)$ where p varies from 0 to 0.9 along the games with 0.1 increments. In the 1X scale experiment, the levels of payoffs are $\left(x_{Al}, x_{Ah}, x_{Bl}, x_{Bh}\right) = (\$1.6, \$2.0, \$0.1, \$3.85)$ while in 10X experiment all the levels are ten times higher. Outcome was determined by two rolls of a ten sided die, one is to determine which of the ten games is used, the other is to determine the prize. Differences in expected payoffs are shown in column 4. In the first 4 games, option A has a higher expected payoff, while it has a lower payoff in the last 6 games. Under EUT, only risk loving individuals would choose B in the first five games, while risk averse individuals choose A in the last four games. Game 10 is just to test whether subjects are understanding the experiment and all subjects should choose B in this game.

An agent should start with Option A in the first game and at some point (on or before Game 10) switch to Option B. Choosing Option B at game j means $pu(3.85) + (1-p)u(0.1) > pu(2) + (1-p)u(1.6)$, or

$$p\left[u(3.85) - u(2)\right] > (1-p)\left[u(1.6) - u(0.1)\right]$$

where p is the probability of winning a higher payoff. Then with any $p' > p$, it must be true that

$$p'\left[u(3.85) - u(2)\right] > (1-p')\left[u(1.6) - u(0.1)\right]$$

This means that once a subject switches to Option B at game j, she/he should not switch back to Option A at a later game. This is also true when applying RDU or CPT in which probabilities are transformed by an increasing function.

We remove all game sessions where subjects made choices that involved more than one switch between safe and risky choices and those in which option A is chosen in game 10. As a result, the final data set includes 162 subjects with 264 game sessions. See Appendix 5 for the percentage of safe choice at each game, and statistics of the sample.

4.5 RESULTS

Estimation results are presented in Table 4.2. Model 1 estimates the single parameter utility function with a random component. The result gives a level of RA of 0.504, which is normally distributed with a standard deviation of 0.231. This implies most subjects are risk averse.

Model 2 has the risk aversion parameter (in the utility function) estimated as a linear function of individual characteristics. In this model, older subjects, those who played a previous game session (variable *order*) and U.S. citizens are more risk averse. The signs and magnitudes of this model are consistent with interval regression in Harrison *et al*. (2005).

Model 3 further introduces the scale function and this leads to some variables now having significant estimated effects on the RA measure. The scale function indicates that business students, graduate students and female students are more systematic in their choices. Surprisingly, students with low GPAs and high GPAs (relative to those with average GPA) are more systematic in their choices. Finally, games at the 10X scale have lower variance than 1X scale. In Model 3, black students are found to be more risk averse, while business students, those who expect to complete Ph.D. or professional degree, and those with low GPA are found to be more risk loving. In addition, the effects of age, order and U.S. citizen are higher than in Model 2.

Models 4 and 5, which are RDU models, yield very different results than the EU models. Although the variable *order* has the same sign and is significant, older subjects and U.S. citizens are no longer more risk averse in these models. In addition, business and low GPA students as well as female subjects are now found to be more risk averse. In Model 4, graduate students are also found to be more risk averse. Moreover in the scale function, choices in 10X sessions now have higher variance, indicating that people are less systematic in their choices in 10X games.

To test the RDU model (Model 5) against the EU model (Model 3), we test the null hypothesis that $\gamma = 0$ and $\rho_k = 0 \ \forall k$ (that is all parameters in the weighting function are equal to zero simultaneously). A likelihood ratio test yields a p-value lower than 0.001 and suggests that the null hypothesis can be rejected.

Model 4 has a random component only in its weighting function, while Model 5 has one in both the weighting and utility functions. In Model 5, the standard deviation of the random component in the weighting function is larger than that in the utility function. A likelihood ratio test of Model 5 against Model 4 suggests that the null hypothesis that Model 5 is not better than Model 3 cannot be rejected, indicating that the main source of heterogeneity is in subjective perception of probabilities, not in attitude toward risk.

Table 4.2: Estimation results of EU and RDU models

	Model 1: Simple EU	Model 2: EU	Model 3: EU + scale	Model 4: RDU	Model 5: Full RDU
Log-likelihood	-884.47	-875.78	-559.17	-507.87	-507.79
Rho-square	0.52	0.52	0.69	0.72	0.72
Run time (a)	0.5	45	150	378	395
SCALE FUNCTION					
BUSINESS			**0.347† (0.138)**	**0.975† (0.311)**	**0.982† (0.314)**
FEMALE			**0.851† (0.122)**	**1.31† (0.279)**	**1.31† (0.285)**
GPAHI			**0.783† (0.196)**	0.854 (0.539)	0.871 (0.561)
GPALOW			**0.987† (0.137)**	**1.16† (0.325)**	**1.16† (0.328)**
GRADUATE			**0.93† (0.204)**	**0.787† (0.288)**	**0.788† (0.321)**
X10			**1.27† (0.307)**	**-1.54† (0.544)**	**-1.53† (0.554)**
UTILITY FUNCTION (r)					
$\bar{r}_0$	**0.504† (0.024)**	-0.034 (0.266)	**-0.284* (0.173)**	-0.383 (0.41)	-0.381 (0.416)
σ_r	**0.231† (0.025)**	**0.214† (0.026)**	**0.395† (0.018)**		0.032 (0.081)
AGE (years)		**0.017* (0.011)**	**0.028† (0.006)**	-0.008 (0.015)	-0.008 (0.015)
BLACK		0.09 (0.069)	**0.117Υ (0.059)**	0.116 (0.082)	0.117 (0.084)
BUSINESS		-0.047 (0.05)	**-0.1Υ (0.042)**	**0.457† (0.144)**	**0.46† (0.144)**
EDEXPECT		-0.085 (0.059)	**-0.136† (0.042)**	-0.062 (0.077)	-0.062 (0.077)
EDFATHER		0.041 (0.062)	0.029 (0.033)	0.053 (0.064)	0.051 (0.088)
EDMOTHER		-0.001 (0.057)	0.014 (0.03)	-0.05 (0.059)	-0.05 (0.072)
FEMALE		0.065 (0.052)	0.035 (0.04)	**0.522† (0.133)**	**0.527† (0.135)**
GPAHI		-0.009 (0.061)	0.064 (0.048)	0.323 (0.229)	0.333 (0.239)
GPALOW		-0.093 (0.06)	**-0.214† (0.058)**	**0.438† (0.154)**	**0.438† (0.157)**
GRADUATE		0.007 (0.111)	0 (0.061)	**0.225* (0.129)**	0.229 (0.178)
JUNIOR		-0.009 (0.081)	0.008 (0.07)	0.01 (0.088)	0.009 (0.09)
ORDER		**0.081* (0.048)**	**0.286† (0.022)**	**0.372† (0.106)**	**0.376† (0.109)**
SENIOR		-0.028 (0.085)	-0.014 (0.065)	-0.003 (0.095)	0 (0.096)
SOPHOMORE		-0.031 (0.074)	0.01 (0.053)	-0.101 (0.083)	-0.102 (0.085)
USCITIZEN		**0.153Υ (0.082)**	**0.296† (0.046)**	-0.056 (0.104)	-0.055 (0.107)
PROBABILITY WEIGHTING FUNCTION					
GAMMA				**0.658† (0.269)**	**0.641Υ (0.28)**
$\bar{\rho}_0$				0.555 (0.829)	0.595 (0.831)
σ_p				**1.00† (0.177)**	**0.986† (0.188)**
AGE				0.047 (0.031)	0.046 (0.031)
BLACK				0.087 (0.306)	0.067 (0.307)
BUSINESS				**-1.00† (0.29)**	**-1.01† (0.293)**
EDEXPECT				-0.34 (0.243)	-0.329 (0.248)
FEMALE				**-0.515* (0.309)**	**-0.531* (0.311)**
GPAHI				-0.44 (0.438)	-0.448 (0.444)
GPALOW				**-1.01† (0.35)**	**-1.02† (0.346)**
WON				**-0.428† (0.147)**	**-0.421† (0.147)**
USCITIZEN				**0.514Υ (0.252)**	**0.507Υ (0.258)**
X10				**0.474† (0.174)**	**0.455Υ (0.194)**

*Note: (a) in minutes, on a computer with a six-core processor at 3.47GHz. † Significant at 1% level. Υ Significant at 5% level. * Significant at 10%. Standard errors are in parentheses. All the following of variables are dummies: BUSINESS: major is in business; EDEXPECT: expect to finish a Ph.D. or Professional degree; GPAHI: GPA > 3.75; GPALOW: GPA < 3.24; X10: games in 10X scale; EDFATHER: father completed college; EDMOTHER: mother completed college; SOPHOMORE, JUNIOR, SENIOR and GRADUATE indicates student type; ORDER: played a previous game session; WON: Won the higher prize in the previous game session; USCITIZEN: U.S. citizen.*

Because $\gamma > 0$, there is an inflection point and subjects appear to underweight small probabilities and overweight large probabilities. However for the average subject, the inflection point is too close to one of the two end points such that there is no intersection with the 45-degree line. On average ($\rho_0 = \overline{\rho}_0$), subjects tends to overweight all low-outcome probabilities and thus underweight all high-outcome probabilities, which implies pessimism. Figure 4.1 presents the probability weighting function for different groups. Figure 4.1a illustrates an average probability weighting function for 1X and 10X scales games by gender. Figure 4.2a presents those for 10X games only, for the two groups of those who won the higher prize in the previous session and those who did not, again by gender. The X-axis measures the objective probability and the Y-axis the subjectively weighted probabilities of both low and high outcomes. All the subjectively weighted probabilities of low outcomes are above the 45-degree line, and thus all the subjectively weighted probabilities of high outcome are below the 45-degree line. Therefore the average subject is pessimistic.

Subjects are more pessimistic when facing the larger scale game. In Figure 4.1a, the low-outcome probability weighting curve of 10X scale is above that of 1X curve. The reverse is true for high-outcome probability weighting curve: the 10X curve is below the 1X curve. Female subjects are more optimistic than male subjects. In RDU models, female subjects are found to be more optimistic, while at the same time they are more risk averse. This is different from the EU models which found that female subjects are not significantly more risk averse than male subjects.

(a) By gender and scale of the game

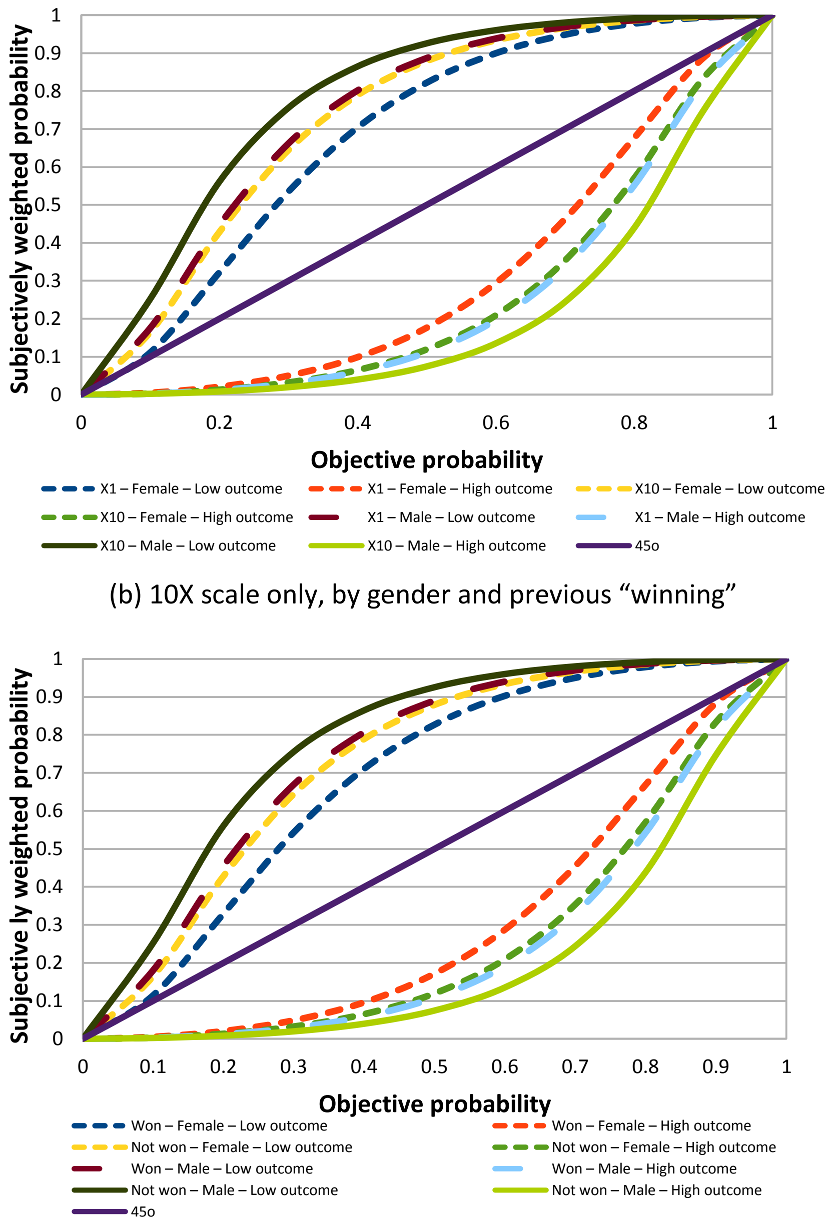

Figure 4.1: Probability weighting functions

Subjects who won higher outcomes in the previous game session appear to be more optimistic in the next session, although still pessimistic. In Figure 4.1b, the low-outcome probability weighting curve of those who won is below that of those who did not, for both male and female subjects. On the other hand, subjects are less likely to underweight high-outcome probabilities if they won a higher prize in the previous session. However the high-outcome weighted probability of those who won is still lower than the objective probabilities. Even though wining a previous game appears to make subjects more optimistic, subjects are still pessimistic overall.

U.S. citizen subjects are found to be more risk averse in the EU models. However in the RDU models, their levels of RA are not found to be significantly different from non-U.S. citizens, but are found to be more pessimistic.

Low GPA students and business students, who are more likely to take the risky option, are no longer found to be more risk loving. They are actually more risk averse. They probably take the risk because they are more optimistic, according to RDU model results.

There are some differences in the scale factor between EU and RDU models. In RDU models, the 10X game sessions have higher error variance terms, although the contrary is found in EU models. This means subjects are less systematic in the larger scale games in RDU models. In RDU models, high GPA students no longer have smaller variance error terms.

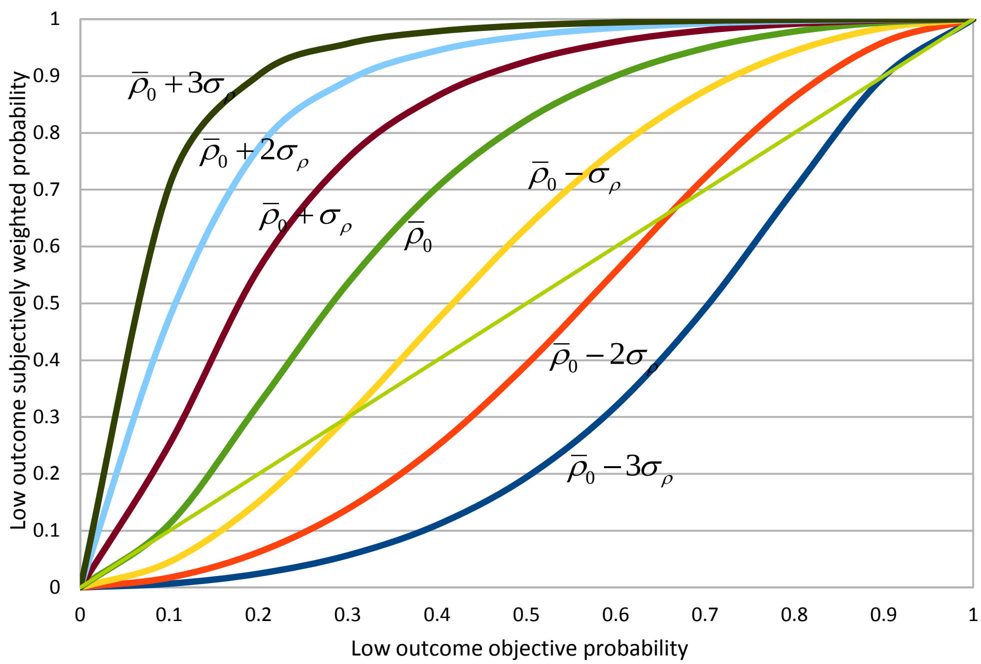

Figure 4.2: Probability weighting function of a U.S. citizen, 21 year old female subject at 1X scale games at different standard deviations

Figure 4.2 presents the low-outcome probability weighting function for a U.S. citizen female student at the average age of 21.19 while playing 1X games. Note that the probability weighting function includes a random component that is normally distributed $\rho_0 \sim N\left(\bar{\rho}_0, \sigma_\rho^2\right)$. Figure 4.2 presents the probability weighting function at different levels of $\bar{\rho}_0$, ranging from $\bar{\rho}_0 - 3\sigma_\rho$ to $\bar{\rho}_0 + 3\sigma_\rho$. Figure 4.2 indicates that subjects are very heterogeneous in terms of subjective perception of probabilities. At $\bar{\rho}_0 - 3\sigma_\rho$, the subject is moderately optimistic because low-outcome probabilities are underweighted in almost of all the domain of probability. While at $\bar{\rho}_0 + 3\sigma_\rho$, the subject is extremely pessimistic.

Table 4.3: Risk aversion estimate for a representative subject(*) from different models

	Model 1: Simple EU	Model 2: EU	Model 3: EU with scale	Model 4: RDU	Model 5: Full RDU
RA measure	0.50	0.56	0.67	-0.08	-0.09
Std deviation	0.23	0.21	0.40	0 (fixed)	0.03

(*) A U.S. citizen, 21.19 years of age, female senior student, whose parents completed college.

In general, subjects in RDU models are pessimistic, but less risk averse than in EU models. Table 4.3 presents the RA measures from models. In Models 1-3, subjects are risk averse, while in Models 4-5, which are RDU models, subjects are slightly risk loving. Probably for these small payoffs, subjects are risk loving but pessimistic. As a result, measuring RA using EUT-based methods may be incorrect when applied to small payoffs.

4.6 DISCUSSION

We applied a mixed nonlinear logit model to estimate probability weighting and utility functions. We found that with the small payoffs used for the experiment, subjects appear to avoid risks not because they are risk averse, but because they are pessimistic. Under RDU models, subjects are found to be risk neutral, and this result is consistent with Rabin (2000) who shows that subjects are risk neutral for small amounts of money. Estimates of the effect of individual characteristics on RA are found to be very different in the RDU model compared to EU models. The mixed logit model allows for heterogeneity among subjects in terms of RA as well as incidental emotions. In addition, we include the scale function to account for heteroskedasticity and found that omitting scale factors may result in overestimation of the parameters[7]. We found that there is heteroskedasticity and thus ignoring the scale factor might result in biased estimates of parameters. Therefore, estimates of RA measures under EUT, especially those using the Holt and Laury data type, may need to be re-considered.

It is well known in the literature, that the weighting function is typically an inverted S-shaped, implying subjects overweight small probabilities and underweight large probabilities (for example Preston and Baratta 1948, Tversky and Kahneman 1992, Camerer and Ho 1994, Wu and Gonzalez 1996, Abdellaoui 2000, Fehr-Duda *et al*. 2011). However the weighting function we found indicates that subjects underweight small probabilities and overweight large probabilities. This is inconsistent with the conventional finding, but not the only exception. Camerer and Ho (1994), who used data from other researchers to estimate weighting and value functions under different theoretical settings, also revealed some cases of S-shaped weighting functions.

There are several possible reasons for our unusual results. First, there may be hypothetical bias in those who found an inverse S-shaped weighting function. Harrison and Rutström (2008) pointed out that many utility elicitation procedures are not incentive compatible. The data we use is from a real money experiment. This is possibly the reason why our average subject systematically underweights the probabilities of lower outcomes over the entire domain, except near the two bounds. Second, many researchers used certainty equivalent (CE) data, which may be subject to inaccuracy in cases where subjects have a (dis)utility of gambling. Third, many researchers have used

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[7] A likelihood ratio test of Model 3 against Model 2 yields a p-value lower than 0.001.

very small probabilities, i.e. 0.01 or 0.05, while in our data the smallest probability is 0.1. Subjects may have been unable to process accurately these small probabilities. Finally, the inverted S-shaped weighting function is good at explaining why subjects purchase lotteries and insurance at the same time. However these are cases involving extreme outcomes, which do not apply to the data we use.

Our result suggesting that subjects are more optimistic after winning a higher outcome is consistent with other research. Winning a higher prize may produce a better mood, and this makes people more optimistic. Johnson and Tversky (1983), Wright and Bower (1992), and Fehr-Duda *et al*. (2011) found that risks are perceived to be higher if subjects are in a negative mood and vice versa. Our result that female subjects have a probability weighting function that differs from the linear weighting of male subjects is different from previous research (Fehr-Duda *et al*. 2011). This may be because we included gender in the scale function, which shows that women are more systematic about their choices than men. This means that although men are found to have less deviation in their SP function, relative to EU, they also appear to have higher error variance than women.

This research provides some evidence that the RDU model explains choices under uncertainty better than the EUT framework. The result that subjects appear not to be risk averse, but risk loving and pessimistic, suggests that ignoring the weighting function may result in incorrect estimates of RA, and that EUT-based models which ignore the weighting function may be inappropriate.

In summary, our research makes a number of recommendations for the analysis of lottery choice to measure RA. First, it is important to include the weighting function for objective probabilities. Second, the scale factor should be incorporated. Third, random parameters should be considered to be included in the utility function as well as the weighting function. Finally, emotional factors should be considered for the weighting function. These can help to develop a better analytical framework to analyze choice under risk and uncertainty, which can be helpful for many fields including finance and production economics.

Because the payoff levels of the data used in this research are relatively low, further tests need to be undertaken to examine RA and probability weighting at higher amounts of money. Finally, it would be useful to find measures correlated with pessimism/optimism at the individual level to assess whether the model results found here can be triangulated with other metrics of perception.

REFERENCES

Abdellaoui, M. 2000. Parameter-free Elicitation of Utility and Probability Weighting Functions. *Management Science* 46(11): 1497-1512.

Abdellaoui, M., H. Bleichrodt and C. Paraschiv. 2007. Measuring loss aversion under prospect theory: A parameter-free approach. *Management Science* 53(10): 1659-1674.

Andersen, S., J. Fountain, G. Harrison, A. Hole M. Lau and E. Rutström. 2012. Non-linear Mixed Logit. *Theory and Decision* 73(1): 77-96.

Andersen, S., J. Fountain, G. Harrison, A. Hole, and E. Rutström. 2011. Inferring Beliefs as Subjectively Imprecise Probabilities. *Theory and Decision:* forthcoming.

Andersen, S., J. Fountain, G. Harrison and E. Rutström. 2010. Estimating Subjective Probabilities. *Center for the Economic Analysis of Risk, Georgia State University, Working paper* WP 2010-06.

Arrow, K.J. 1965. Aspects of the Theory of Risk-Bearing. Helsinki: Yrjö Jahnssonin Saatiö.

Ben-Akiva, M. and S. R. Lerman. 1985. Discrete Choice Analysis: Theory and Application to Travel Demand. MIT, Cambridge.

Bierlaire, M. 2003. BIOGEME: A free package for the Estimation of Discrete Choice Models. *Proceedings of the 3rd Swiss Transportation Research Conference. Ascona. Switzerland*.

Binswanger, H.A. 1980. Attitudes toward Risk: Experimental Measurement in Rural India. *Journal of Agricultural Economics* 62(3): 395-407.

Bleichrodt, H. and J.L. Pinto. 2000. A Parameter-free Elicitation of the Probability Weighting Function in Medical Decision Analysis. *Management Science* 46(11): 1485-1496.

Bruhin, A. H. Fehr-Duda and T. Epper. 2010. Risk and Rationality: Uncovering Heterogeneity in Probability Distortion. *Econometrica* 78(4): 1375-1412.

Camerer, C. 1995. Individual decision making. In J.H. Kagel & A.E. Roth (eds.), *The Handbook of Experimental Economics* (pp. 587-703). Princeton, NJ: Princeton University Press.

Camerer, C. and T. Ho. 1994. Violations of the Betweenness Axiom and Nonlinearity in Probability. *Journal of Risk and Uncertainty* 8: 167-196.

Davidson, D., P. Suppes and S. Siegel. 1957. Decision-making: an experimental approach. Stanford: Stanford University Press.

Eckel, C.C. and P.J. Grossman. 2008. Forecasting risk attitudes: An experimental study using actual and forecast gamble choices. *Journal of Economic Behavior & Organization* 68: 1-17.

Edwards, W. 1955. The prediction of decisions among bets. *Journal of Experimental Psychology* 51: 201-214.

Edwards, W. 1962. Subjective Probabilities Inferred from Decisions. *Psychological Review* 69(2): 109-135.

Fehr-Duda, H., T. Epper, A. Bruhin and R. Schubert. 2011. Risk and Rationality: The Effects of Mood and Decision Rules on Probability Weighting. *Journal of Economic Behavior & Organization* 78: 14-24.

Fennema, H. and M. van Ansen. 1999. Measuring the utility of losses by means of the trade of method. *Journal of Risk and Uncertainty* 17(3): 277-295.

Fishburn, P.C. 1878. On Handa's "New Theory of Cardinal Utility" and the Maximization of Expected Return. *Journal of Political Economy* 86: 321-324.

Friedman, M. and L.P. Savage. 1948. The Utility Analysis of Choices involving Risk. *Journal of Political Economy* 56: 279-304.

Goldstein, W.M. and H.J. Einhorn. 1987. Expression Theory and the Preference Reversal Phenomena. *Psychological Review* 94(2): 236-254.

Gonzalez, R. and G. Wu. 1999. On the Shape of the Probability Weighting Function. *Cognitive Psychology* 38: 129-166.

Handa, J. 1977. Risk, Probabilities and a New Theory of Cardinal Utility. *Journal of Political Economy* 85(1): 97-122.

Harrison, G., E. Johnson, M. McInnes and E. Rutström. 2005. Risk Aversion and Incentive Effects: Comments. *American Economic Review* 95(3): 897-901.

Harrison, G. and E. Rutström. 2008. Risk Aversion in the Laboratory. *Research in Experimental Economics* 12: 41-196.

Harrison G.W., S. Humphrey and A. Vershoor. 2010. Choice under Uncertainty: Evidence from Ethiopia, India and Uganda. *The Economic Journal* 120: 80-104.

Hershey, J. C., H.C. Kunreuther and P.J.H. Schoemaker. 1982. Sources of bias in assessment procedures for utility functions. *Management Science* 28(8): 936-954.

Hey, J. D. and C. Orme. 1994. Investigating Generalizations of Expected Utility Theory Using Experimental Data. *Econometrica* 62(6): 1291-1326.

Holt, C. A. and S. K. Laury. 2002. Risk Aversion and Incentive Effects. *American Economic Review* 92(5): 1644-55.

Holt, C. A., and S. K. Laury. 2005. Risk aversion and incentive effects: New data without order effects. *American Economic Review* 95(3): 902–912.

Johnson, E.J. and A. Tversky. 1983. Affect, Generalization and the Perception of Risk. *Journal of Personality and Social Psychology* 45(1): 20-31.

Kahneman, D. and A. Tversky. 1979. Prospect Theory: An Analysis of Decision under Risk. *Econometrica* 42(7): 263-291.

Lattimore, P.K., J.R. Baker and A.D. Witte. 1992. The Inference of Probability on Risky Choice. *Journal of Economic Behavior and Organization* 17: 377-400.

Luce, R.D. and P. Suppes. 1965. Preference Utility and Subjective Probability. In Luce, R.D. *et al*. (eds.) *Handbook of Mathematical Psychology*. New York: John Willey & Sons.

Menzes C.F. and D.L. Hanson. 1970. On the theory of Risk Aversion. *International Economic Review* 11(3): 481-487.

Mosteller, F. and P. Nogee. 1951. An experimental measurement of utility. *Journal of Political Economy* 59: 371-404.

Pratt, J.W. 1964. Risk Aversion in the Small and in the Large. *Econometrica* 32:122-136.

Preston, M.G. and P. Baratta. 1948. An Experimental study of the auction-value of an uncertain outcome. *American Journal of Psychology* 61: 183-193.

Quiggin, J. 1981. Risk Perception and the Analysis of Risk Attitudes. *Australian Journal of Agricultural Economics* 25(2): 160-169.

Rabin, M. 2000. Risk Aversion and Expected-Utility Theory: A Calibration Theorem. *Econometrica* 68: 1281-1292.

Savage, L.J. 1954. The Foundations of Statistics. New York, NY: Wiley

Schmeidler, D. 1989. Subjective Probability and Expected Utility without Additivity. *Econometrica* 57(3): 571-587.

Schoemaker, P.J. 1982. The Expected Utility Model: Its Variants, Purposes, Evidence and Limitations. *Journal of Economic Literature* 20: 529-563.

Starmer, C. 2000. Developments in Non-Expected Utility Theory: The Hunt for a Descriptive Theory of Choice under Risk. *Journal of Economic Literature* 38: 332-382.

Toda, M. 1951. Measurement of intuitive-probability by a method of game. *Japanese Journal of Psychology* 22: 29-40.

Toda, M. 1958. Subjective inference vs. Objective inference of sequential dependencies. *Japanese Psychological Research* 5: 1-20.

Tversky, A. and C.R. Fox. 1995. Weighting Risk and Uncertainty. *Psychological Review* 102(2):269-283.

Tversky, A. and D. Kahneman. 1992. Advances in Prospect Theory: Cumulative Representation of Uncertainty. *Journal of Risk and Uncertainty* 5: 297-323.

von Neumann J. and O. Morgenstern. 1944. Theory of Games and Economic Behavior. Princeton University Press, Princeton.

Wakker, P. and D. Deneffe. 1996. Eliciting von Neumann-Morgenstern Utilities when Probabilities are Distorted or Unknown. *Management Science* 42(8): 1131-1150.

Wilcox, N. T. 2011. ‘Stochastically more risk averse:’ A contextual theory of stochastic discrete choice under risk. *Journal of Econometrics* 162: 89-104.

Wright, R.W. and G.H. Bower. 1992. Mood Effects on Subjective Probability Assessment. *Organizational Behavior and Human Decision Processes* 52: 276-291.

Wu, G. and R. Gonzalez. 1996. Curvature of the Probability Weighting Function. *Management Science* 42(12): 1676-1690.

Zeckhauser, R. and E. Keeler. 1970. Another type of Risk Aversion. *Econometrica* 38: 661-665.

CHAPTER 5: CONCLUSIONS

This thesis consists of three studies that examine key assumptions of the Random Utility Model (RUM). Each study either proposes new methods of relaxing the assumptions of RUM, or evaluates methods of relaxing the assumptions. The first study examines methods of relaxing the assumption that decision makers make choices from a fully known choice set. The second study proposes a new technique to estimate non-compensatory utility functions. The third study investigates the personal perceptions of attribute levels using structural models. The thesis also provided information for policy analysis.

The first study examines the choice set formation processes by comparing the basic RUM to a fully endogenous choice set model using the Independent Availability Logit (IAL) model and an implicit availability model (Cascetta and Papola, 2001) that approximates choice set formation, using the response of Albertan hunters to chronic wasting disease (CWD) risk. The study find that choice set formation plays an important role in the decision making process. When comparing the two methods of choice set formation, we find that the approximations of choice set formation of Cascetta and Papola (2001) may not adequately reflect choice set formation and capture such effects. As a result, one may want to consider the IAL model when analyzing choice behavior with choice set formation process.

We find that CWD risk affects utility parameters in site choice evaluation as well as choice set formation, and these effects change over time. The study also finds that welfare measures from models with and without choice set formation are different. As a result, incorporating choice set formation in analyses of choice behavior is important.

The comparison between the Cascetta and Papola Availability (CPA) model and the IAL model provides some similar results. However it appears that the Cascetta and Papola approach generates a somewhat different set of parameters for the availability function. This may imply that the Cascetta and Papola approach provides a poor approximation of the formal choice set formation in this case. This result is consistent with Bierlaire *et al*. (2010).

We find that welfare measures from the choice set formation models are quite different from those without choice set formation. This implies that ignoring choice set formation may result in misleading welfare measures. However this also suggests that additional investigation of the structure of choice set formation, and the capability of choice set formation models to capture such processes, is required for the correct welfare measures.

The sample used in this study may be not representative, but if it is, the welfare measures provided can be helpful for policy makers in designing management program to combat CWD in Alberta. The welfare measures can be used to compare to the costs of management provided by Pybus (2007) to perform a cost-benefit analysis which is useful for designing the optimal management plan. Costs of CWD management can be substantial and the effectiveness of CWD control programs is uncertain, therefore information that helps in comparing costs and benefits is important for policy choices. This study also finds that hunters preferences for CWD changes over time. In particular hunters are more likely to dislike sites with CWD in second year. This implies that welfare from CWD management programs may become higher in later years when hunters become more sensitive to CWD. This result, together with results from previous research (Zimmer *et al*. 2012), highlights the need to continue to evaluate the economic aspects of CWD management plans.

The study also contributes to the literature by incorporating a scale parameter and a temporal dimension into availability models. We found that the MNL model with a scale function outperforms one without it, indicating that ignoring scale factors may result in biased parameter estimates.

The second study relaxed the assumption of non-compensatory preference. It investigated cutoffs, which are the point at which a change in one attribute is no longer able to be compensated by a change in another attribute; or it is still able to be compensated for, but with a penalty. Cutoffs are usually elicited directly from the respondents, which may result in biased parameter estimates. The contribution of the second paper is the construction of an analytical model to estimate cutoffs endogenously. Our approach provides a tractable way to estimate models of non-compensatory preferences without prior information about self-reported cutoffs. The proposed analytical model is relevant to cases where non-compensatory preferences may be appropriate but information of self-reported cutoffs is not available. Our model relies on variables such as individual characteristics having enough explanatory power to the modeled cutoff values.

After testing the model using synthetic data and finding that the estimates of the model are very close to the true parameters, we applied the model to a real-world data set. The data were collected from a survey in Alberta about choices of caribou conservation options. Our model shows improvement over basic MNL models, indicating that it is important to include cutoffs in empirical analyses. The MNL model with self-reported cutoffs has a higher measure of goodness of fit, but this may not be a good metric to use to evaluate models. We estimate cutoffs for two attributes: herd (number of self-sustaining caribou herds) and bid (annual cost of the conservation strategy). The bid cutoff estimated from our model is close to the self-reported cutoff. However estimated herd cutoffs are half the size of the self-reported herd cutoff. This may be because when respondents make the choice, they adjust their cutoffs or are willing to violate their cutoffs when evaluating an alternative. Therefore, we suggest that a model with endogenous cutoff like our proposed model is considered even when information on stated cutoffs is available. The results from our estimation that the herd cutoff is about 5 to 7 herds implies that, on average, additional herds beyond these levels may not be always desirable. This result, together with the result that respondents are willing to pay no more than $120-$170/household/year can be helpful economic information for designing the conservation strategy for woodland caribou. In addition, the welfare measures from this study can be compared to the opportunity costs of woodland caribou conservation in Alberta provided by Schneider *et al*. (2010) in a cost benefit framework, which is necessary for the action plan required by the *Species At Risk Act* in Canada as woodland caribou are listed as "Threatened".

Finally, we found that some of the estimated coefficients of the cutoff functions from the proposed model are close to those from Poisson regressions of self-reported cutoffs on corresponding demographics, and most are consistent in signs with those Poisson regressions.

The third study explored structural models that allow for subjective perception of attributes. This study analyzed experimental data of choice under uncertainty, in which subjects choose from two alternatives, each with two outcomes at different probabilities of occurring. This data were used to measure risk aversion. The study found that subjective perception of probabilities may play a significant role in the measurement of risk aversion.

The third study applies a mixed nonlinear logit model to estimate probability weighting and utility functions. We apply a non-Expected Utility model, specifically the Rank Dependent Utility (RDU) to analyze choices under uncertainty. We found that with the small payoffs used for the experiment, subjects appear to avoid risks not because they are risk averse, but probably because they are pessimistic. Estimates of the utility function parameters are found to be very different in the RDU model compared to EU models. The mixed logit model allows for investigating heterogeneity among subjects in terms of RA measures and incidental emotions and we found that the heterogeneity in probability weighting is higher than that of RA measures. In addition, we investigate heteroskedasticity by incorporating the scale function and found that omitting scale factors may result in biased estimation of risk aversion measures. Therefore, estimating RA measures under EUT and ignoring heterogeneity and heteroskedasticity may need to be re-considered.

Results from our analyses suggest that when analyzing choices under risk and uncertainty using a choice model, scale factors, random parameters for utility and weighting functions, and emotional factors for the weighting function should be considered. This is expected to provide better estimates of risk aversion and subjective weighting of probabilities which can be important for many fields such as finance and production economics.

Subjective perception of probabilities appears to play an important role in the decision making process. It may be affected by a number of factors. We found that subjects are more optimistic after winning a higher outcome. This is consistent with other research. Subjects winning a higher prize may produce a better mood, and this makes people more optimistic (Johnson and Tversky, 1983, Wright and Bower, 1992, and Fehr-Duda *et al*., 2011). This result suggests that there are dynamics underlying the model and it may be important to separate the dynamics in subjective perception of probabilities from the possibility that risk aversion parameters change in response to previous choices.

A number of broader issues arise from our investigation. First, there is a relationship between choice set formation and non-compensatory preference structures (e.g. Swait 2001, Hauser 2010). Given that both choice set formation and non-compensatory preferences play important roles in the choice process, further research untangling the difference between these two representations of choice processes is required. The linkage between cutoff models we investigate and models of choice set formation deserves further analysis.

Second, estimating cutoffs using our proposed analytical model requires variables that adequately explain the cutoffs. Finding the right specification for the cutoff function seems to be quite important. The model is also limited to a Poisson distribution of cutoff error, two-alternative choices, and possible multiple solutions. However, as it appears that cutoffs are important to include in empirical analyses, further work is needed to develop an approach that estimates non-compensatory preferences without stated elicitation of cutoffs.

Finally, the third study found that subjective measures of attributes, or perception of attributes is important in evaluating choices. However the results of these models need triangulation. Results from structural model should be compared to subjective probabilities elicited from other methods including experiments. Perceptions may be important in environmental valuation as well. It is worth investigating the structural models applied in this study for cases of environmental valuation where attributes may be subjectively perceived. For triangulation in these cases, the results from such studies should be compared to the approach proposed by Adamowicz *et al*. (1997).

As outlined in Ben-Akiva *et al*. (1999), the psychological factors that affect the decision making process include memory, motivation and affect, perceptions and beliefs, preferences, and process. This thesis may have partially addressed some of those factors, specifically process (choice set formation study), preference and taste (cutoffs) and subjective evaluation or perception. All the extensions explored in the thesis appeared to outperform the standard MNL, and they made non-trivial changes. Choice set formation and cutoff made significant differences in welfare measures, and the models with subjective perceptions indicated that subjects are risk neutral, compared to risk aversion in standard models. However, further studies are required to better understand the relationship between choices, choice sets, perceptions and preferences. This will include development of theory, particularly around choice set formation and non-compensatory preferences, and the continued empirical assessment of alternative model frameworks.

REFERENCES

Adamowicz, W., J. Swait, P. Boxall, J. Louviere and M. Williams. 1997. Perceptions Versus Objective Measures of Environmental Quality in Combined Revealed and Stated Preference Models of Environmental Valuation. *Journal of Environmental Economics and Management* 32: 65–84.

Ben-Akiva, M, D. McFadden, T. Gärling, D. Gopinath, J. Walker, D. Bolduc, A. Börsch-Supan, P. Delquié, O. Larichev, T. Morikawa, A. Polydoropoulou, V. Rao. 1999. Extended Framework for Modeling Choice Behavior. *Marketing Letters* 10(3): 187-203.

Bierlaire, M., R. Hurtubia and G. Flötteröd. 2010. Analysis of Implicit Choice Set Generation Using a Constrained Multinomial Logit Model. *Transportation Research Record* 2175: 92-97.

Cascetta, E., A. Papola, 2001. Random utility models with implicit availability/perception of choice alternatives for the simulation of travel demand. *Transportation Research Part C* 9 (4): 249–263.

Fehr-Duda, H., T. Epper, A. Bruhin and R. Schubert. 2011. Risk and Rationality: The Effects of Mood and Decision Rules on Probability Weighting. *Journal of Economic Behavior & Organization* 78: 14-24.

Hauser, J.R. 2010. Consideration-Set Heuristics. Forthcoming, *Journal of Business Research*. http://web.mit.edu/hauser/www/Papers/Hauser%20Consideration%20Heuristics%20JBR%202011.pdf

Johnson, E.J. and A. Tversky. 1983. Affect, Generalization and the Perception of Risk. *Journal of Personality and Social Psychology* 45(1): 20-31.

Pybus, M. 2007. Alberta's chronic wasting disease response program: March, 2007. Alberta Sustainable Resource Development. http://www.srd.alberta.ca/FishWildlife/WildlifeDiseases/ChronicWastingDisease/documents/AlbertaCWDResponseProgram-ExecutiveSummary-March2007.pdf. Assess November 27, 2012.

Schneider, R.R., G. Hauer, W. L. Adamowicz and S. Boutin. 2010. Triage for conserving populations of threatened species: The case of woodland caribou in Alberta. *Biological Conservation* 143: 1603-1611.

Swait, J.D. 2001. A non-compensatory choice model incorporating attribute cut-offs. *Transportation Research Part B* 35 (7): 903–928.

Wright, W.F. and G.H. Bower. 1992. Mood Effects on Subjective Probability Assessment. *Organizational Behavior and Human Decision Processes* 52: 276-291.

APPENDICES

6.1 APPENDIX 1: CWD SURVEY 2009

Research team:

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NOTE: The survey will be administered on computers (internet based) and will not look exactly like this paper copy. However it will look very similar to this version (but with boxes to click on rather than items to circle, etc.)

Deer hunting in Alberta: priorities and preferences

The following questions are meant to collect information regarding your deer hunting trips taken in Alberta and your opinions about wildlife resources in Alberta. Your answers will help us to understand preferences for hunting and create better

Which weapon(s) do you hunt deer with? Please circle all that apply.

Rifle   Cross bow   Bow and arrow   Shotgun   Muzzleloader

Have you ever taken a hunting training course?   Yes   No

If yes, how old were you when you completed it? __________

What land do you typically hunt deer on in Alberta?

Private   Crown   Both

What wildlife management unit (WMU) would you list as your favourite WMU to hunt deer in? ___________

Have you hunted deer outside the province in the last five years? Yes No

Have you hunted deer outside the country in the last five years? Yes No

Please rate the following statements about quality deer hunting attributes on a scale of 1 (not important) to 5 (very important).

	Not Important				Very Important
Seeing deer and interacting with wildlife.	**1**	**2**	**3**	**4**	**5**
Having the thrill of hunting/adventure	**1**	**2**	**3**	**4**	**5**
Harvesting a deer	**1**	**2**	**3**	**4**	**5**
Having a relaxing and restful time	**1**	**2**	**3**	**4**	**5**
Harvesting a trophy buck	**1**	**2**	**3**	**4**	**5**
Just being outside and close to nature	**1**	**2**	**3**	**4**	**5**
Harvesting a doe/fawn	**1**	**2**	**3**	**4**	**5**
Being far away from a city/town	**1**	**2**	**3**	**4**	**5**
Not seeing any other hunters and not being disturbed	**1**	**2**	**3**	**4**	**5**
Having time to myself	**1**	**2**	**3**	**4**	**5**
Good access to the hunting area (e.g. paved roads, 2WD access)	**1**	**2**	**3**	**4**	**5**
Making use of my outdoor/hunting skills	**1**	**2**	**3**	**4**	**5**
Close proximity to a cabin or lodge to which I have access thereby allowing day hunting trips	**1**	**2**	**3**	**4**	**5**
Familiarity with the hunting area	**1**	**2**	**3**	**4**	**5**
Bringing food home	**1**	**2**	**3**	**4**	**5**
Spending time with my family and friends	**1**	**2**	**3**	**4**	**5**

If for some reason you could not hunt deer next season in your usual hunting area(s), what would you do instead? Please circle all that apply.

a) Hunt deer in another area(s) in Alberta
b) Hunt another species but in the same area
c) Hunt another species in another area
d) Hunt deer outside the province
e) Go camping
f) Engage in wildlife viewing/hiking/photography
g) Go fishing
h) Play indoor sports
i) Stay at home

Now, out of the reasons chosen above, which one would be the most important alternative?___________________________________

Think of a typical deer hunting trip that you participated in during 2008. Please estimate your expenditures in the following areas for that trip. A trip involves travel to and from a hunting site, and may involve one or more days at the site.

- **Please provide an estimate of how much you spent in total, and, approximately, the percentage of the total that you spent in the WMU.**
- **If you split the cost of the trip with other people, please give the amount *you personally* spent.**
- **If you spent nothing in a category, please put a 0 in the total amount cell.**
- **If you bought a package with everything included, please indicate the amount of the package under "Other." If there were additional expenditures, beyond the package, in any of the categories, please indicate how much they were; otherwise just write $0 for each of them.**

Expenditure category	**Total amount**	**% spent in hunting region**
Gas for vehicles (including ATVs)		
Accommodations (e.g. RV rentals, camping fees, motels)		
Guiding fees		
Food and beverages (e.g. restaurants, groceries, liquor stores, etc.)		
Equipment for hunting (including ammunition, clothing, and camping supplies if necessary)		
License fees		
Butchering (including cutting and packaging)		

Other (please specify)		

In this next section we ask you to recall deer hunting trips that you personally took on during the past years (2008 season). Please recall as much information as possible and be as specific as possible. There are calendars available if you wish to

Please complete the following table for the 2008 hunting season. You are asked to indicate the following:

1. This is the overall number of trips made to that WMU during the entire hunting season. Please note that if there were multiple destinations or overnight trips, the number of trips to that WMU may not equal the number of days spent there. A trip is defined as travel to and from a hunting site and may involve one or more days at a site.

2. Please write down the closest town/city or landmark where you hunted. For example, you could write down, Battle River near the Saskatchewan border or Paradise Valley. If you hunted in various places in the WMU, please choose a town or landmark most central to all the areas hunted in, or the most commonly visited area where you hunted.

3. The total nights stayed would only be applicable for overnight trips. If only day trips were made to that WMU, place a 0 in that column.

4. Please indicate how many years you have previously hunted in that WMU. If this is your first season hunting there, the number should be 0.

5. This would be the total number of days spent in that WMU for the entire season. Please think of the number of trips you took and how long you spent there.

Example

Please complete the following table for each deer hunt you went on during the 2008 hunting season.

WMU hunted in	Number of trips to the WMU	Nearest landmark or town to where you hunted	Total nights stayed on location	How many years have you previously hunted in this WMU?	Total number of days
148	0		0	0	0
150	0		0	2 years	0
151	5	Empress	6	1 year	11
162	0		0	0	0
163	0		0	0	0
200	0		0	0	0
234	0		0	0	0
236	0		0	0	0
256	3	Marwayne	1	10 years	3
500	0		0	0	0
Please indicate any other WMUs you hunted in.					
164	1	Coronation	1	5 years	2

Please complete the following table for each deer hunt you went on during the 2008 hunting season.

WMU hunted in	Number of trips to the WMU	Nearest landmark or town to where you hunted	Total nights stayed on location	How many years have you previously hunted in this WMU?	Total number of days
148					
150					
151					
162					
163					
200					
234					
236					
256					
500					
Please indicate any other WMUs you hunted in.					

In this section we are trying to determine what is important to you during deer hunting trips and how the presence of wildlife disease may affect your hunting decisions. Please read all the information presented first and then answer the

Please read the following information about chronic wasting disease.

Chronic wasting disease (CWD) is a disease caused by prions which are infectious proteins that cause small lesions and the sponginess of the brain. It is a similar disease to mad cow disease in cattle and scrapie in sheep.

The animal will exhibit significant weight loss over a period of time, lowering of the head, walking in a repeated pattern, excessive drooling and grinding teeth, and decreased relationships with other animals.

It is not currently known how CWD spreads. The disease is likely transferred through animal to animal contact although this has not been scientifically confirmed. It is very resistant to environmental conditions such as direct sunlight or rain, and therefore the disease can exist in a contaminated area for quite awhile.

Currently, there is no cure for CWD. This disease is limited to infecting cervids: deer, elk, and moose. No cases have been reported of CWD transferring to livestock. While the possibility of transmission to humans is a concern, it is important to note that there have been no verified cases of humans contracting CWD.

For safety's sake, hunters are still told not to eat the meat of the infected animal and to take precautions when handling the carcass of a potentially infected animal.

Do you feel CWD is a threat to wildlife herd health in Alberta?

a) Yes, I feel it is a threat.
b) I feel it is present but is not currently a threat.
c) No, I feel it is not a threat.
d) I am not sure or I need more information.

Do you feel CWD is a threat to human health?

a) Yes, I feel it is a threat.
b) I feel it is present but is not currently a threat.
c) No, I feel it is not a threat.
d) I am not sure or I need more information.

What do you think CWD will do to deer hunting in the province of Alberta over the next 10 years?

a) The amount of hunting will decrease.
b) The amount of hunting will increase.
c) The amount of hunting will be unchanged.
d) I am not sure or I need more information.

If there was an additional extended season in October for hunting in CWD infected areas, would you participate?

Yes No

Currently the government is conducting a variety of programs to address CWD in the province of Alberta. Please rate your satisfaction with these programs on a scale of 1 (very dissatisfied) to 5 (very satisfied).

	Very Dissatisfied				Very Satisfied	Don't Know
Culling of herds in the areas where CWD is most concentrated.	**1**	**2**	**3**	**4**	**5**	**DK**
Mandatory submission of heads to Fish and Wildlife for testing in certain WMUs.	**1**	**2**	**3**	**4**	**5**	**DK**
Voluntary submission of heads for the province.	**1**	**2**	**3**	**4**	**5**	**DK**
Materials for educational purposes placed on Sustainable Resource Development's website.	**1**	**2**	**3**	**4**	**5**	**DK**
Open public meetings to discuss CWD.	**1**	**2**	**3**	**4**	**5**	**DK**
Mailouts and advertisements in local newspapers.	**1**	**2**	**3**	**4**	**5**	**DK**
Provisions of freezer locations for deer head submission.	**1**	**2**	**3**	**4**	**5**	**DK**

Providing additional quota deer licenses in certain WMUs when heads are submitted for testing.	**1**	**2**	**3**	**4**	**5**	**DK**
Research of the prion, its properties, and the disease itself.	**1**	**2**	**3**	**4**	**5**	**DK**

Indicate using the scale of "Strongly Disagree" to "Strongly Agree," your agreement with the statement by checking the appropriate space:

"Obtaining knowledge of these programs can be done relatively easily."

(Strongly disagree) __ __ __ __ __ (Strongly agree)

We would like to know how extensive and how serious you think CWD currently is in the wild deer population in certain areas of Alberta.

Please complete the chart below for each WMU provided. Please circle what you think the correct infection rate is for each WMU. We want to find out what you think the infection rates are. There is no right or wrong answer. We provide 4 categories of severity based upon the number of infected deer per 100 in each WMU. The infection rates are explained in the table below.

Infection Rate	**Infected Deer per 100**
None	0
Low	1 to 5
Medium	6 to 10
High	10 or more
Don't know	I don't know how many deer are infected.

Please circle what you think is the correct infection rate for CWD in each of the WMUs for 2008.					
148	**None**	**Low**	**Medium**	**High**	**Don't Know**
150	**None**	**Low**	**Medium**	**High**	**Don't Know**
151	**None**	**Low**	**Medium**	**High**	**Don't Know**
162	**None**	**Low**	**Medium**	**High**	**Don't Know**

163	**None**	**Low**	**Medium**	**High**	**Don't Know**
200	**None**	**Low**	**Medium**	**High**	**Don't Know**
234	**None**	**Low**	**Medium**	**High**	**Don't Know**
236	**None**	**Low**	**Medium**	**High**	**Don't Know**
256	**None**	**Low**	**Medium**	**High**	**Don't Know**
500	**None**	**Low**	**Medium**	**High**	**Don't Know**

In this section we are trying to understand what you would do if deer hunting conditions changed in the areas where you normally hunt. Please read the following instructions carefully then answer the proceeding questions.

In this section, you will be presented with a number of tables. Each table will contain the same WMUs you were asked about in previous questions. Along with the WMUs will be the number of trips you stated as having taken in 2008. Following this will be different scenarios as to whether CWD is present in the area, whether extra tags are being offered for that area, and whether the government is proceeding with active herd culling in the WMU.

You are then asked to decide how many hunting trips you would take to each WMU given the different scenarios. Please treat each scenario as if it was a real situation. Look at the various levels for CWD occurrence, number of extra tags offered, and government culling in the area, then assess exactly how many trips you would take in the next season if these were the actual conditions present in each WMU. Please assume that nothing else will change in those areas other than the conditions presented to you.

The infection rates for wild deer herds are reflected in the following rates. They are listed as the *number of infected animals in every 100 deer* in the herd.

None – 0 deer infected per 100

Low – 1 to 5 deer infected per 100

Medium – 6 to 10 deer infected per 100

High – Greater than 10 deer infected per 100

Scenario 1

WMU	Number of trips in 2008	Prevalence of CWD	Extra tags	Active culling in area	Number of trips you would take in 2009
148		None	No	No	
150		Medium	Yes	Yes	
151		Medium	Yes	Yes	
162		None	No	No	
163		None	No	No	
200		None	No	No	
234		Medium	Yes	Yes	
236		None	No	No	
256		None	No	No	
500		None	No	No	
Other WMUs		None	No	No	

Scenario 2

WMU	Number of trips in 2008	Prevalence of CWD	Extra tags	Active culling in area	Number of trips you would take in 2009
148		Low	Yes	No	
150		Medium	No	No	
151		Medium	Yes	Yes	
162		Low	No	Yes	
163		None	No	No	
200		Low	No	Yes	
234		Medium	Yes	No	
236		Low	Yes	No	
256		None	No	No	
500		Low	Yes	Yes	
Other WMUs		None	No	Yes	

Scenario 3

WMU	Number of trips in 2008	Prevalence of CWD	Extra tags	Active culling in area	Number of trips you would take in 2009
148		Medium	Yes	Yes	
150		Medium	No	Yes	
151		Medium	No	No	
162		None	No	No	
163		None	Yes	Yes	
200		None	Yes	Yes	
234		Medium	No	No	
236		None	Yes	Yes	
256		None	Yes	No	
500		Low	No	No	
Other WMUs		None	No	Yes	

The following are some statements regarding hunter behaviour and CWD. Please indicate using the scale of 1 (strongly disagree) to 5 (strongly agree) your agreement with the statement.

	Strongly Disagree				Strongly Agree
I have changed where I normally hunt because of CWD.	**1**	**2**	**3**	**4**	**5**
I no longer consume deer meat because of CWD.	**1**	**2**	**3**	**4**	**5**
CWD has had no affect on my hunting activities.	**1**	**2**	**3**	**4**	**5**
I have not hunted in a CWD affected area.	**1**	**2**	**3**	**4**	**5**
I have changed which species I normally hunt due to CWD.	**1**	**2**	**3**	**4**	**5**
I regularly submit my deer heads for CWD testing to Fish and Wildlife.	**1**	**2**	**3**	**4**	**5**
If the frequency of CWD was decreased, I would increase my hunting in Alberta.	**1**	**2**	**3**	**4**	**5**
CWD has affected my enjoyment of hunting deer.	**1**	**2**	**3**	**4**	**5**
If CWD were found in the WMU where I received a trophy buck tag, I would still hunt in that WMU.	**1**	**2**	**3**	**4**	**5**
I think baiting and the use of scents help to promote the spread of CWD.	**1**	**2**	**3**	**4**	**5**
I think game farms contribute to the spread of CWD.	**1**	**2**	**3**	**4**	**5**
I think hunters should report back to landowners if there was a CWD positive animal found on their land.	**1**	**2**	**3**	**4**	**5**

I eat or give away the deer meat before I get CWD results back from Fish and Wildlife.	**1 2 3 4 5**

Now we would like to ask some questions about you. The next set of questions are to help us find similarities between different groups of people and to identify trends in the hunting population. Please be ensured that your responses will be kept

Are you:

Male Female

Are you a member of any of the following organizations?

a) Alberta Professional Outfitter Society
b) Alberta Conservation Association
c) Alberta Fish and Game Association
d) Sierra Club
e) Canadian Parks and Wilderness Society
f) Nature Conservancy of Canada
g) Alberta Federation of Naturalists

How old are you? _________ years old

What is the highest level of schooling you have completed? Please circle the correct answer.

Some high school or less

High school diploma

Some university, college, or technical school

Technical school graduate

University/College graduate

Some graduate school

Graduate degree

Please indicate your household income before taxes in 2008?

Less than 10,000	50,000 to 59,999
10,000 to 19,999	60,000 to 79,999
20,000 to 29,999	80,000 to 99,999
30,000 to 39,999	100,000 to 149,999
40,000 to 49,999	greater than 150,000

How many people contribute to your household income? _________

Please indicate, by circling the most appropriate choice, where you currently live.

Large urban setting (100 000 people or more)

Small urban setting (20 000 to 99 999 people)

Town or village (1 000 to 19 999 people)

Rural setting (999 people or less)

Are there any children, under 12, in your household? Yes No

If yes, how many? ________

What are the first three digits of your postal code? _____________

Please indicate your place of residence (nearest village, town, or city).

____

6.2 APPENDIX 2: CARIBOU CONSERVATION SURVEY IN ALBERTA

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6.2.1 PART 1: WORKSHOP POWERPOINT PRESENTATION

Outline

- Species at Risk Legislation
- Background on Woodland Caribou
- Reasons for population decline
- Relationship with resource industries
- Caribou conservation
- Considering caribou conservation options

Partners in this Project

Funded by the Social Sciences and Humanities Research Council of Canada (SSHRC)

Letters of support:

- Alberta Sustainable Resource Development
- Alberta Caribou Committee
- Environment Canada
- Canadian Association of Petroleum Producers
- Alberta Pacific Forest Industries

Background

Species at risk legislation
Description and significance of species
Population trends

Species at Risk

- Legislation provides legal protection and recovery plans for species at risk of extinction
- Canada: *Species at Risk Act* (2003)
- Alberta: *Wildlife Act* (2000)
- Woodland caribou are listed as 'threatened' both federally and provincially (COSEWIC 2002, GOA 2010b)

Requirements of Legislation

www.yfwmb.yk.ca

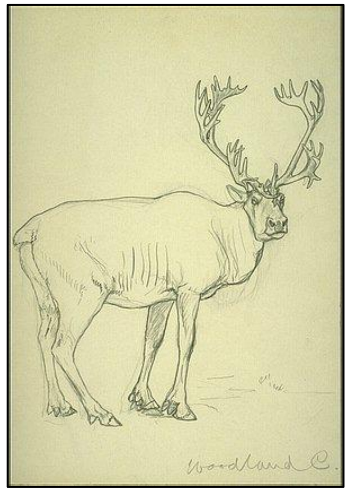
- Identify both long term and short term actions for a species' recovery plan
- Protect critical habitat for those species which are designated as either threatened or endangered
- Provide compensation to individuals where necessary
- Make documents and decisions available to the general public

Species at Risk Legislation in Alberta

Endangered	Threatened	Special Concern
•Whooping crane (*Grus americana*) •Swift fox (*Vulpes velox*)	•Grizzly bear (*Ursus arctos*) **•Woodland caribou (*Rangifer tarandus caribou*)**	•Sprague's pipit (*Anthus spragueii*) •Harlequin duck (*Histrionicus histrionicus*)

Caribou in Canada

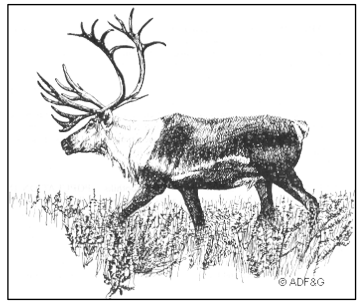
- Four subspecies exist:
  - **Woodland Caribou** (Boreal Forests)
  - Peary Caribou (Arctic)
  - Barren Ground Caribou (Alaska, NWT)
  - Grant's Caribou (Alaska, Yukon)
- Fifth subspecies: Dawson's Caribou declared extinct in 1984 (Rothfels and Russell 2005)



cidc.library.cornell.edu

Woodland Caribou

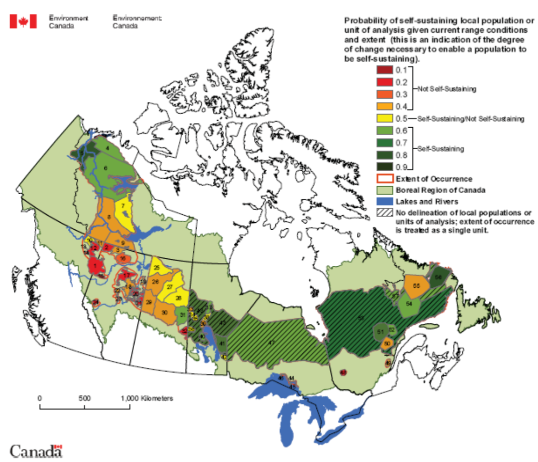
- Medium-sized members of deer family
- Feed on lichen, forbs, shrubs
- Live in large stands of undisturbed mature to old forests
- Found in low densities
- Slow to reproduce
- Average lifespan 8-10 years
- 2 Ecotypes: Boreal Caribou versus Mountain Caribou (ACC 2006)



adfg.state.ak.us

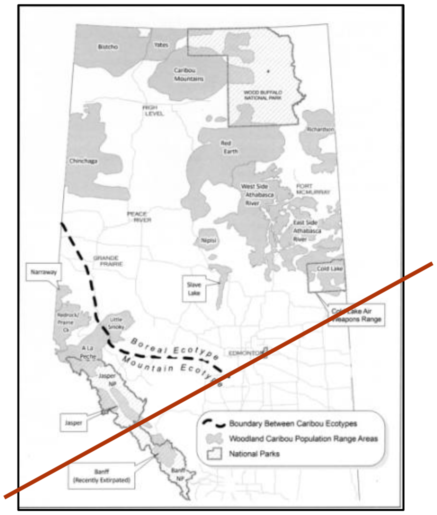
Woodland Caribou in Canada

- Present in boreal forests throughout western Canada and many parts of eastern Canada
- Present distribution of woodland caribou is the entire shaded area



Environment Canada 2008

Woodland Caribou in Alberta



ASRD and ACA 2010

- There are 14 caribou herds in Alberta
- Exist primarily in northern regions of Alberta (ACC 2006)
- In the past caribou range included approximately all of the area north of the red line (Soper 1964)
- Estimated population: 2608-2849

Reasons for Population Decline

Habitat Change
Predation
Other

Habitat Change

www.capp.ca

globalforestwatch.ca

- Oil, gas and forestry
- Create roads, wellsites, seismic lines, cutblocks, noise, etc.
- Caribou avoid areas of human development (Dyer *et al*. 2001)
- Development creates both easy access and prime habitat for wolves (Fuller and Keith 1980)
- Habitat fragmentation puts increasing pressure on caribou populations

Predation

- Primary cause of population decline (Sorensen *et al*. 2008)
- Wolves feed on moose, deer and caribou
- Resource industries:
  - Create favorable habitat for moose and deer
  - Allow wolves to move around more easily
- Thus, changes in habitat have resulted in more interactions between wolves and caribou – resulting in caribou population decline

tangischools.org

Other Reasons for Decline

- Fire (Sorensen *et al*. 2008)
- Traffic collisions

  (Thomas and Gray 2002)
- Spread of agriculture and mining
- Disease and parasites
- Weather and climate

  (Dzus 2001)

www.jumpthecurve.net

The main cause of caribou decline

- Historically, caribou have coexisted with predators
- Today, woodland caribou are threatened
- Conclusion (Sorensen *et al*. 2008):
  - Predation is not the sole reason for the caribou decline
  - Large-scale human developments have played a significant role
- Caribou conservation will proceed if steps are taken to mitigate the effects of industry and resource extraction

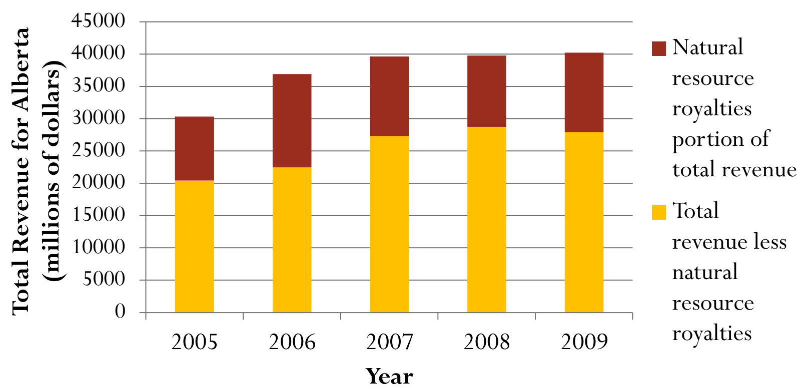
Resource Industries

Alberta's Revenue

Alberta's Expenditure

Alberta's Revenue

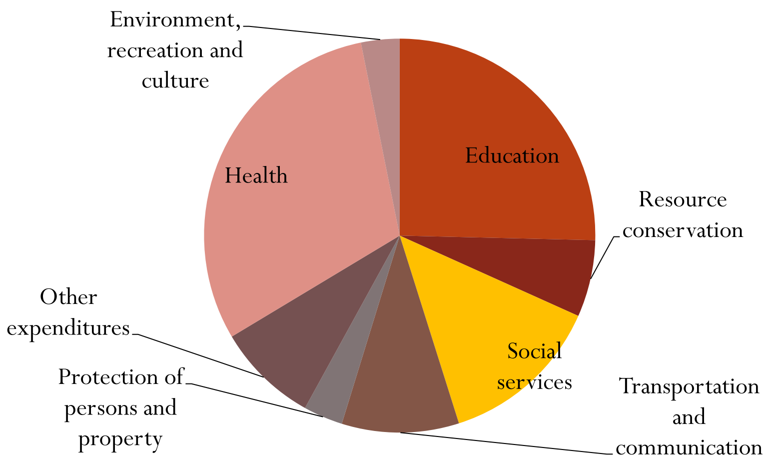
- Royalties: approximately 30% of total revenue
- Corporate income taxes: approximately 10% of total revenue



Statistics Canada

Alberta's Expenditure

- This revenue is used to fund public services:



Caribou Conservation

Importance of caribou conservation

Conservation strategies

Caribou Conservation

- Iconic species of boreal forest
- Cultural importance for aboriginal peoples
- Biodiversity
- Legal requirements of SARA and *Alberta Wildlife Act*
- Benefits of conservation include:
  - Help recover caribou populations
  - Protect old growth stands of boreal forest
  - Protect other natural resources such as water and other species at risk

www.sararegistry.gc

Conservation Strategies

- Predator management or wolf control
- Restrictions on the places that resource extraction industries (energy and forestry sectors) can operate, or restrictions on how quickly these sectors can access the resources
- Increased effort in growing forests in areas previously disturbed by energy and forestry activities

These measures will be costly, and in some cases they will reduce the rate of resource development and thus will reduce tax and royalty revenue collected by the province.

Considering Caribou Conservation Options

Identifying the tradeoff

The basic story

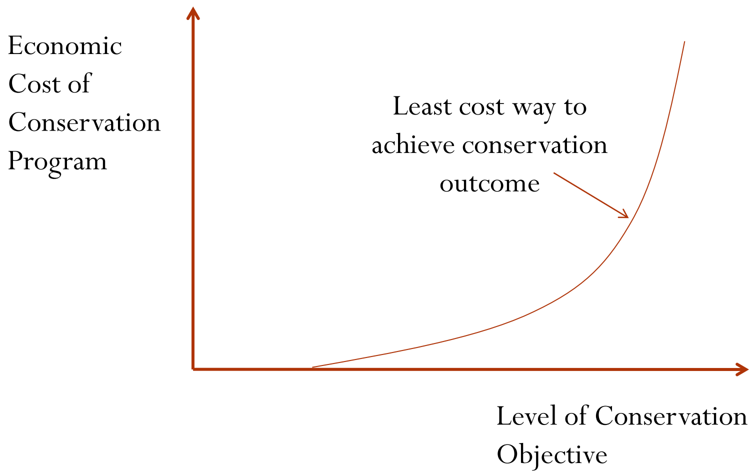
Defining the conservation objectives and costs

Tradeoff

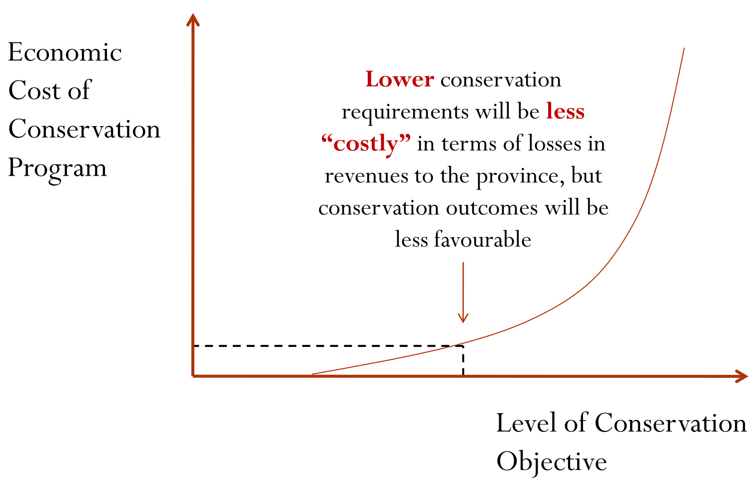
- Decisions will have to be made regarding how much effort to place into caribou conservation and thus how much economic development to postpone
- Conservation actions will reduce economic development through conventional oil and gas, oilsands and forestry
  - Reduction in provincial royalty and tax revenues
- Decision involves public resources: caribou and provincial revenues

We want your opinion concerning the best level of conservation action to engage in

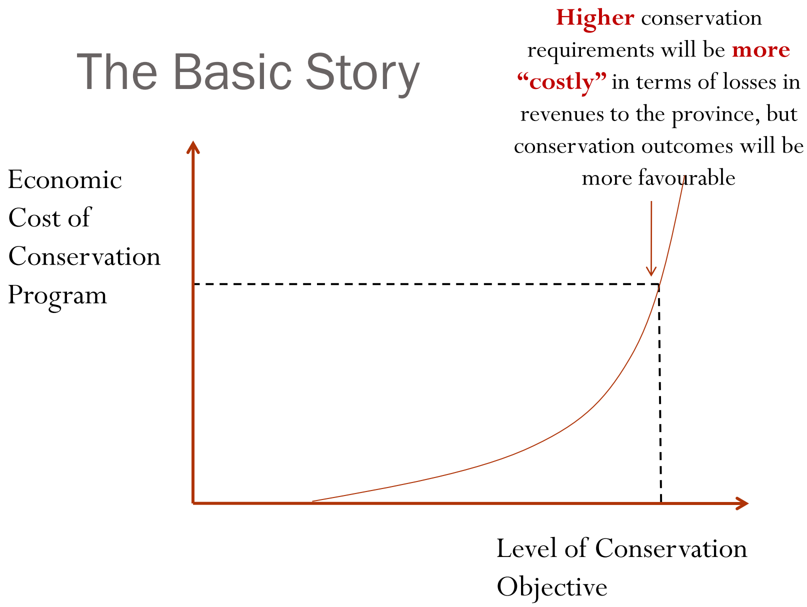
The Basic Story



The Basic Story



The Basic Story

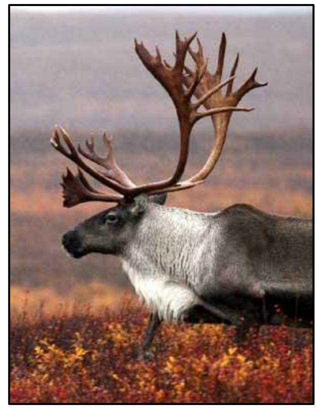


Defining Conservation Objectives and Costs

- Finding the 'least cost' way to achieve the conservation outcome involves defining the costs and benefits of various caribou conservation programs
- "Economic Costs" include:
  - Delayed opportunities for forest harvesting and resource extraction
  - Predator management or wolf control
- "Conservation objectives" include:
  - Ensuring there is sufficient habitat for the caribou through time
  - Ensuring that caribou herds in the future are "self sustaining" or can survive without human intervention
  - We measure these as the number of caribou herds, or the number of caribou, that is self sustaining 50 years from now

Further Defining the Costs

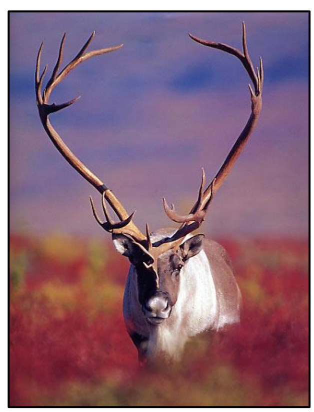
- Economic "Cost" of Conservation Program:
  - *The amount of increase in household taxes, per year for the next 50 years from now, that would be required to maintain revenues and public services ($)*
- Does not include losses in profits that industry will incur



www2.csdm.qc.ca

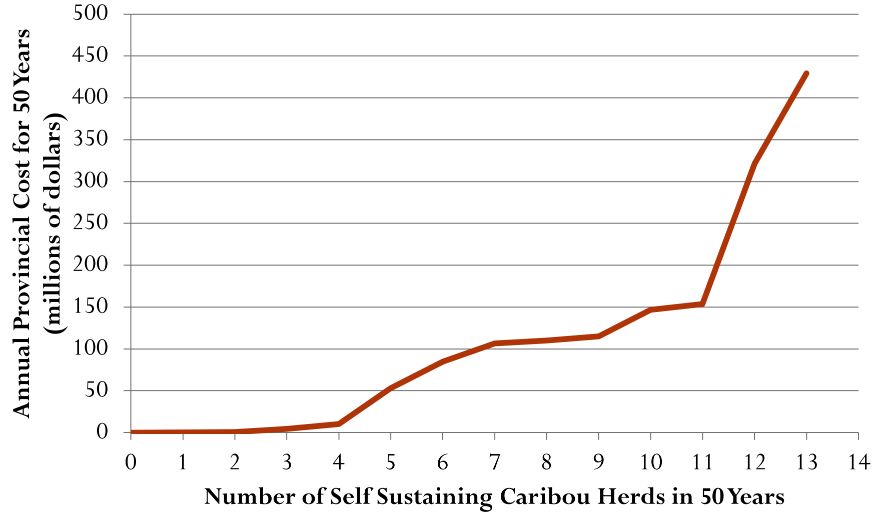
Further Defining Conservation Objectives

- Differing ideas of conservation
  - Habitat
  - Population density
- Level of Conservation Objective:
  - *Number of caribou herds that are nearly guaranteed to be self-sustaining in 50 years from now*
  - There may still be caribou in other regions, but the chances of their survival are uncertain

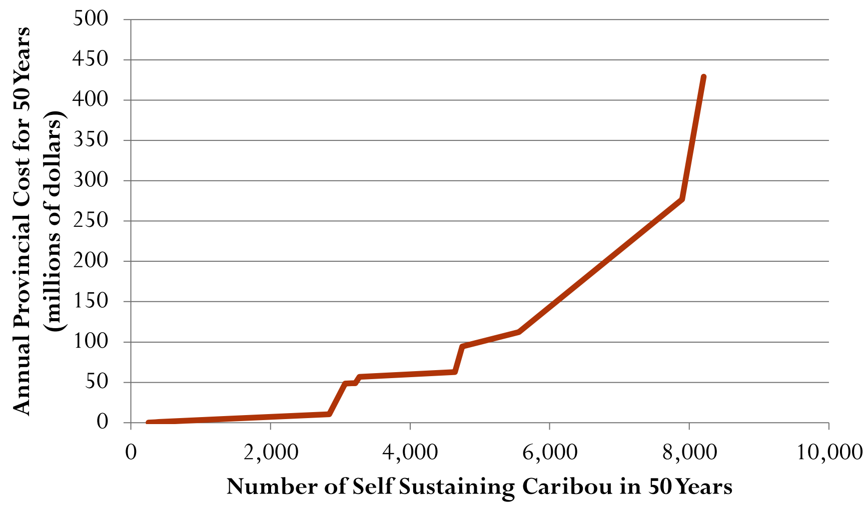


store.wildernesscommitee.org

Identifying the Tradeoff



Identifying the Tradeoff

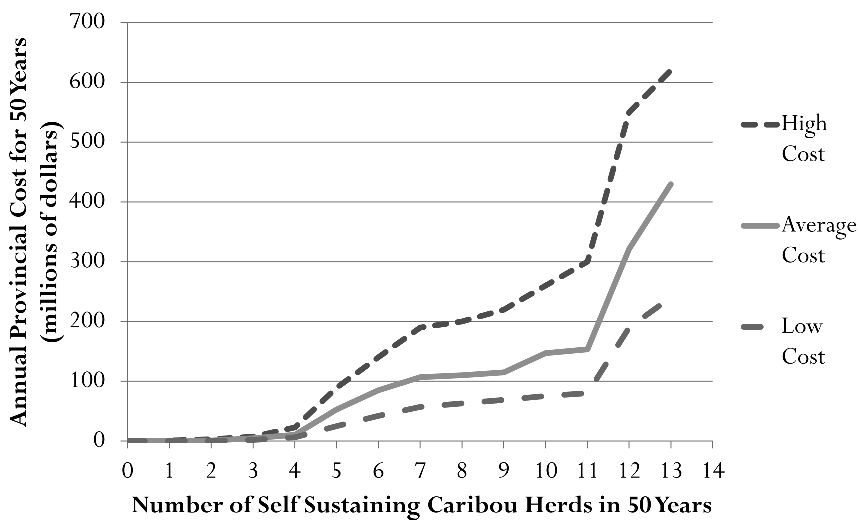


Uncertainty

- Various sources of uncertainty in calculating costs and predicting conservation outcomes:
  - Prices of oil, gas and forest products
  - Costs of energy and forestry extraction
  - Development of new technologies for energy and forestry extraction

These curves have been calculated using the best available information. They represent the best estimates we have of the actual costs associated with the conservation objectives.

Identifying the Tradeoff



Your Turn!

- We need YOUR input to determine what action is sustainable
- Your voice is very important, both to us and to the development of future policy
- Similar information provided on survey

	Current Management Strategy	Proposed Management Strategy
Number of self-sustaining caribou herds *in 50 years*	2	6
Your households' share of the cost in provincial income taxes	$0	$9

References

Alberta Caribou Committee. 2006. Caribou Ecology. Online at http://www.albertacariboucommittee.ca/ index.htm [Assessed June 3, 2010]

Alberta Energy. 2010. About Us: Energy Facts. Government of Alberta. Online at http://www.energy.alberta.ca/About_Us/984.asp [Assessed August 17, 2010]

Alberta Forest Products Association. No date. Our Industry: Facts & Figures. Online at http://www.albertaforestproducts.ca/industry/facts_figures.aspx [Assessed August 17, 2010]

Alberta Sustainable Resource Development. 2000. The General Status of Alberta Wild Species. Alberta Environment, Fish and Wildlife Service, Edmonton, AB. 56 pp.

Alberta Sustainable Resource Development. 2005. The General Status of Alberta Wild Species. Alberta Environment, Fish and Wildlife Service, Edmonton, AB. Online at http://www.srd.alberta.ca/ BioDiversityStewardship/SpeciesAtRisk/GeneralStatus/StatusOfAlbertaWildSpecies2005/Default .aspx [Assessed August 17, 2010]

COSEWIC. 2002. COSEWIC assessment and update status report on the woodland caribou *Rangifer tarandus caribou* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xi + 98 pp

References

Dyer SJ, O'Neill JP, Wasel SM and S Boutin. 2001. Avoidance of industrial development by woodland caribou. *Journal of Wildlife Management* 65, 3: 531-542

Dzus E. 2001. Status of the Woodland Caribou (Rangifer tarandus caribou) in Alberta. Alberta Environment, Fisheries and Wildlife Management Division, and Alberta Conservation Association, Wildlife Status Report No. 30, Edmonton, AB. 47 pp.

Fuller TK and LB Keith. 1980. Wolf population dynamics and prey relationships in northeastern Alberta. *Journal of Wildlife Management* 44: 583-602

Government of Alberta. 2010a. Talk about royalties: Facts on royalties. Accessed online at http://www.energy.alberta.ca/Org/pdfs/FS_Royalties.pdf [September 8, 2010]

Government of Alberta. 2010b. Alberta Species at Risk: Species Assessed by Alberta's Endangered Species Conservation Committee. Assessed online at http://www.srd.alberta.ca/BioDiversityStewardship/SpeciesAtRisk/SpeciesSummaries/documents/SpeciesAssessed-EndangeredSpeciesConservationCommittee-ShortList-Jun03-2010.pdf [September 30, 2010]

Rothfels M and D Russell. 2005. Hinterland Who's Who Mammal Fact Sheets: Caribou. Accessed online at http://www.hww.ca/hww2.asp?id=85 [September 8, 2010]

Soper JD. 1964. The mammals of Alberta. The Hamly Press Ltd., Edmonton, AB. 410 p

Sorensen T, McLoughlin PD, Hervieux D, Dzus E, Nolan J, Wynes B and S Boutin. 2008. Determining sustainable levels of cumulative effects for boreal caribou. *Journal of Wildlife Management* 72, 4: 900-905

Thomas DC and DR Gray. 2002. Update COSEWIC status report on the woodland caribou *Rangifer tarandus caribou* in Canada, *in* COSEWIC assessment and update status report on the Woodland Caribou *Rangifer tarandus caribou* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 1-98 pp

6.2.2 PART 2: WOODLAND CARIBOU CONSERVATION VALUATION PACKAGE

Threatened Wildlife Species in Alberta: Options to Consider

WINTER 2011

A Research Study Funded by the Social Sciences and Humanities Research Council of Canada

Partners in this Project:

Alberta Sustainable Resource Development

Alberta Caribou Committee

Environment Canada

Canadian Association of Petroleum Producers

Alberta Pacific Forest Industries

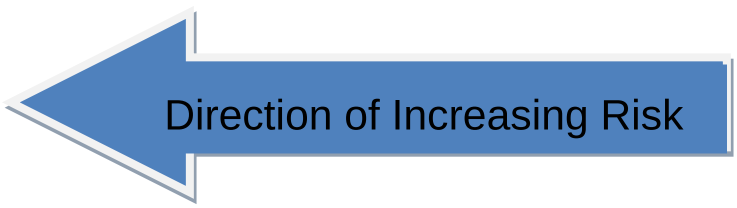
SECTION 1: GENERAL

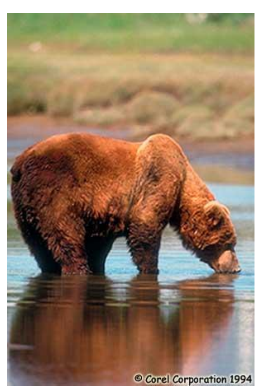
1. The following is a list of some issues facing Canadians. Some may not be important to you, others may be. For each issue, would you say **Canadians** should be doing a lot less, somewhat less, about the same, somewhat more or a lot more than we are today?

	Do a lot less	Do less	Do about the same	Do more	Do a lot more
Reduce air and water pollution					
Protect parks and wildlife reserves					
Protect wildlife from extinction					
Improve roads and highways					
Encourage economic growth and jobs					
Improve health care and prevention					
Improve education					
Reduce taxes					

A number of species in Canada are listed as species at risk of extinction. Species at risk in Canada are protected under the *Species at Risk Act* (2003). Likewise, species at risk are protected provincially under the *Alberta Wildlife Act* (2000). This legislation provides legal requirements for the protection of species at risk of extinction.

According to these Acts, a species is under **increasing risk** as it passes from not at risk to special concern to threatened to endangered. The figure below provides examples of species currently listed for each class in Alberta.



Endangered	Threatened	Special Concern
Swift fox (*Vulpes velox*) 	Grizzly bear (*Ursus arctos*) 	Harlequin duck (*Histrionicus histrionicus*) 

Pictures from http://www.sararegistry.gc.ca/sar/index/default_e.cfm

Please see the Appendix at the end of the survey for definitions of each species at risk category.

3. Before today, had you heard of the *Species at Risk Act*?

- ❑ Yes
- ❑ No
- ❑ Not sure

4. Before today, had you heard of the *Alberta Wildlife Act*?

- ❑ Yes
- ❑ No
- ❑ Not sure

5. How important is it to you personally that every possible effort be made to protect all species that are currently at risk?

- ❑ Not at all important
- ❑ A little important
- ❑ Moderately important
- ❑ Very important
- ❑ Extremely important
- ❑ Not sure

SECTION 3: WOODLAND CARIBOU

6. Before today, how familiar would you say you were with Woodland Caribou?

- ❑ Not at all familiar
- ❑ Not very familiar
- ❑ Somewhat familiar
- ❑ Very familiar
- ❑ Not sure

Caribou are members of the deer family, which also includes moose, elk, white-tailed deer and mule deer. They are most easily identified by their cream-colored neck and large and often complex antlers.

Caribou rely mainly on lichen for food in the winter and on plants, shrubs and other green vegetation in the summer. They prefer large stands of intact mature forest which can take between 60 and 150 years to grow. Caribou are found in low densities over wide areas and are slow to reproduce. This makes them vulnerable to population declines resulting from habitat degradation.

Woodland caribou are declining in North America which has lead to the species being listed as **threatened** both at the federal level by the Committee on the Status of Endangered Wildlife in Canada and at the provincial level by Alberta Sustainable Resource Development and the Alberta Conservation Association (COSEWIC 2002, ASRD and ACA 2010).

Woodland caribou habitat covers the majority of northern Alberta. A significant proportion of the total value of Alberta's oil, gas and forestry resources occurs in areas used by caribou (Schneider *et al*. 2009).

7. Before today, were you aware that Woodland Caribou in Alberta are at risk?

- ❑ Yes
- ❑ No
- ❑ Not sure

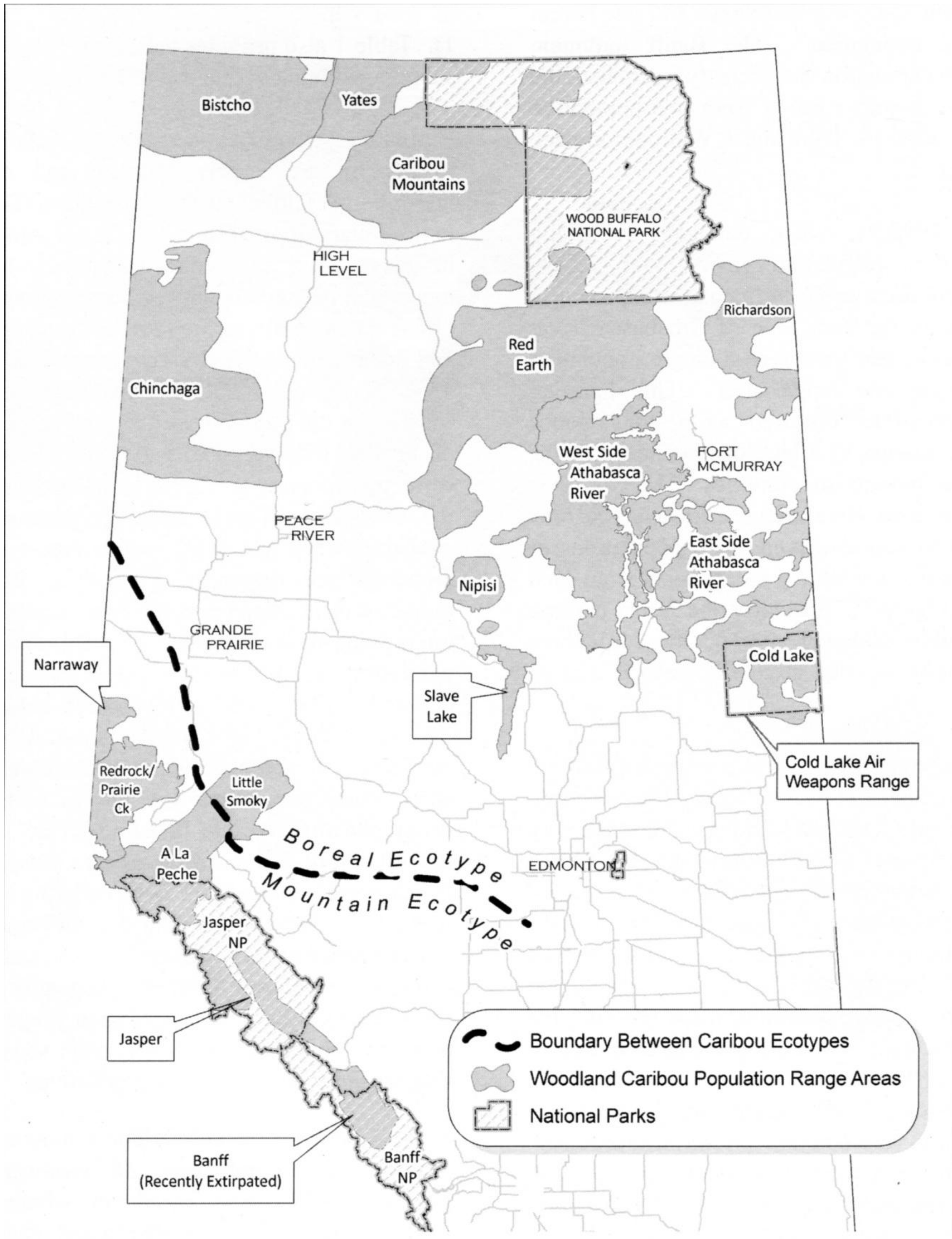
8. Have you ***personally*** ever observed caribou in nature?

- ❑ Yes
- ❑ No
- ❑ Not sure

9. How interested are you in observing caribou in nature in the future?

- ❑ Not at all interested
- ❑ Somewhat interested
- ❑ Very interested
- ❑ Extremely interested
- ❑ Not sure

In Alberta, caribou of the woodland subspecies (*Rangifer tarandus caribou*) are presently found in the northern regions of the province, denoted by the shaded areas on the map below.



ASRD and ACC (2010).

10. Considering the previous information, please indicate the degree to which you agree or disagree with the following statements.

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
It matters to me personally if the caribou populations in Alberta remain at risk					
It matters to me personally if the caribou populations in other parts of Canada are at risk					
Alberta should spend more money so that the caribou populations recover					

Habitat Change	Predation
	
In Alberta, resource extraction industries such as **oil, gas and forestry** occur in areas which are also important habitat for woodland caribou. Caribou will avoid areas used by these industries. As these industries expand further into caribou habitat, the pressure on caribou populations is increased.	An important factor limiting caribou populations are the **predator-prey relationships** between wolves, caribou, moose and deer. Caribou historically protected themselves by choosing to live in habitats that other animals that wolves eat, such as moose, do not live. However, this strategy is no longer very effective.

Pictures from www.globalforestwatch.ca and www.tangischools.org

For century's caribou in the boreal forest lived with predators such as wolves. Caribou have effective strategies for avoiding wolves on natural landscapes where there are few wolves. Resource industries create favorable habitat for moose and deer, leading to more wolves by increasing their food supply. The altered landscape also allows wolves to move around more easily.

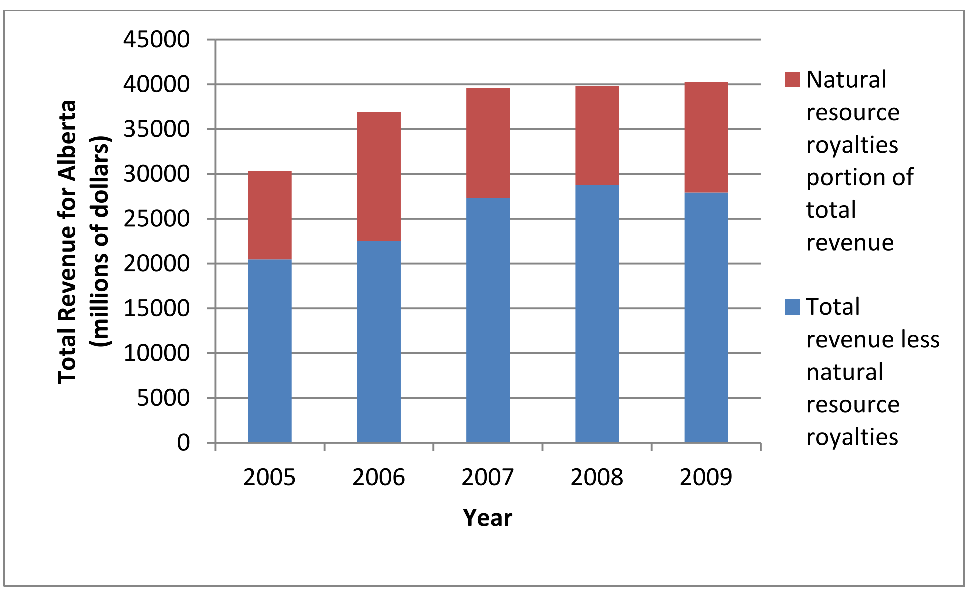
Predation by these more numerous and mobile wolves is the most likely cause of woodland caribou decline. The wolves have become a threat to caribou because resource industries have altered large areas of the forest.

11. Before reading this survey, did you know that resource industries played a role in the decline of caribou?

- ❑ Yes
- ❑ No
- ❑ Not sure

SECTION 5: REVENUE FROM RESOURCE INDUSTRIES

Total revenue for the province of Alberta from 2005 to 2009 is shown in the graph below. Royalties and taxes from resource extraction industries are two important sources of revenue for the province.

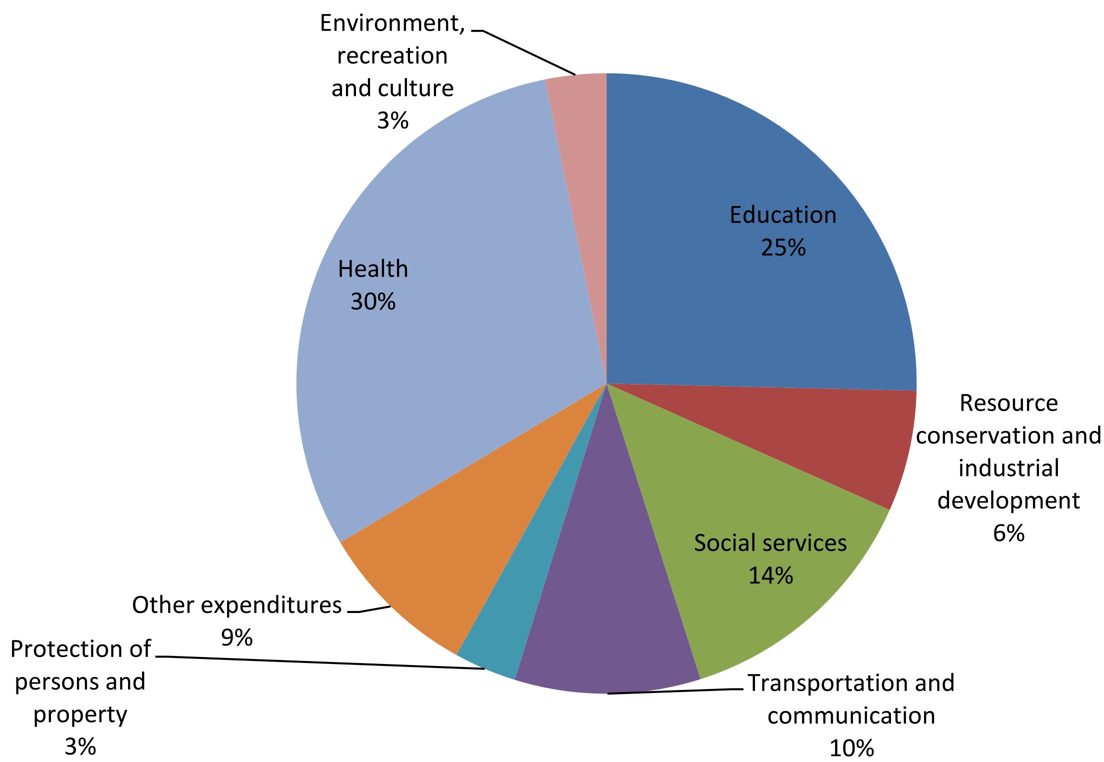


Total revenue for the province of Alberta from 2005 to 2009 (data in millions). Statistics Canada.

Royalties are payments made to the government of Alberta by corporations who have been granted the right to extract natural resources such as forests, oil or natural gas. In 2009, over 30 percent of the Government of Alberta's revenue came from royalties from natural resources.

The taxes that companies pay are called **corporate income taxes**. In 2009, corporate income tax to the Government of Alberta amounted to $3,774,000, which is almost 10 percent of the total revenue collected by the province.

The taxes and royalties collected by the Government of Alberta are used to pay for public services such as the ones shown in the pie chart below (Statistics Canada).



Expenditure categories for the province of Alberta. Statistics Canada.

12. Before reading this survey, did you know that energy and forestry companies made corporate income tax and royalty payments to the Government of Alberta based on the resources they extract?

- ❑ Yes
- ❑ No
- ❑ Uncertain

13. We would also like your opinions about spending on public services. For each of the publicly-provided services listed below, please indicate if you personally think funding for these services should be reduced substantially, reduced somewhat, not changed, increased somewhat or increased substantially.

	Reduced substantially	Reduced somewhat	Not changed	Increased somewhat	Increased substantially
Health					
Environment, recreation and culture					
Education					
Resource conservation and industrial development					
Social services					
Transportation and communication					
Protection of persons and property					
Other expenditures					

SECTION 6: CARIBOU CONSERVATION PROGRAMS

If woodland caribou populations are to be conserved, steps must be taken to minimize and mitigate the effects of industry and resource extraction in important caribou habitat, both now and in the future.

Experts think that the following potential measures, or some combination of these, could be considered as part of a caribou conservation program:

- Predator management or wolf control

- Restrictions on the places that resource extraction industries (energy and forestry sectors) can operate, or restrictions on how quickly these sectors can access the resources
- Increased effort in growing forests in areas previously disturbed by energy and forestry activities

These measures will be costly, and in some cases they will reduce the rate of resource development and thus will reduce tax and royalty revenue collected by the province.

Experts think that a caribou conservation program will:

- Help caribou populations recover to self sustaining levels
- Protect old growth stands of boreal forest
- Protect other natural resources such as water and other species at risk

There are 14 woodland caribou herds in the province of Alberta. The number of caribou in each herd varies from approximately 80 to 350. Different caribou conservation programs will affect certain caribou herds and will have differing costs.

A caribou conservation program is successful for a given herd if that herd becomes **self-sustaining**. A caribou herd is considered to be self-sustaining when its population can be maintained over time on its own.

A more expensive caribou conservation program will likely have more caribou herds which are self-sustaining over time. Similarly, a less expensive caribou conservation program will likely have less caribou herds which are self-sustaining over time.

The time frame used in this study is over the next 50 years from now. Under this time frame, caribou conservation programs are successful if the chosen numbers of caribou herds become self-sustaining in the next 50 years.

---

13. How important do you think the following benefits associated with achieving the caribou conservation program are?

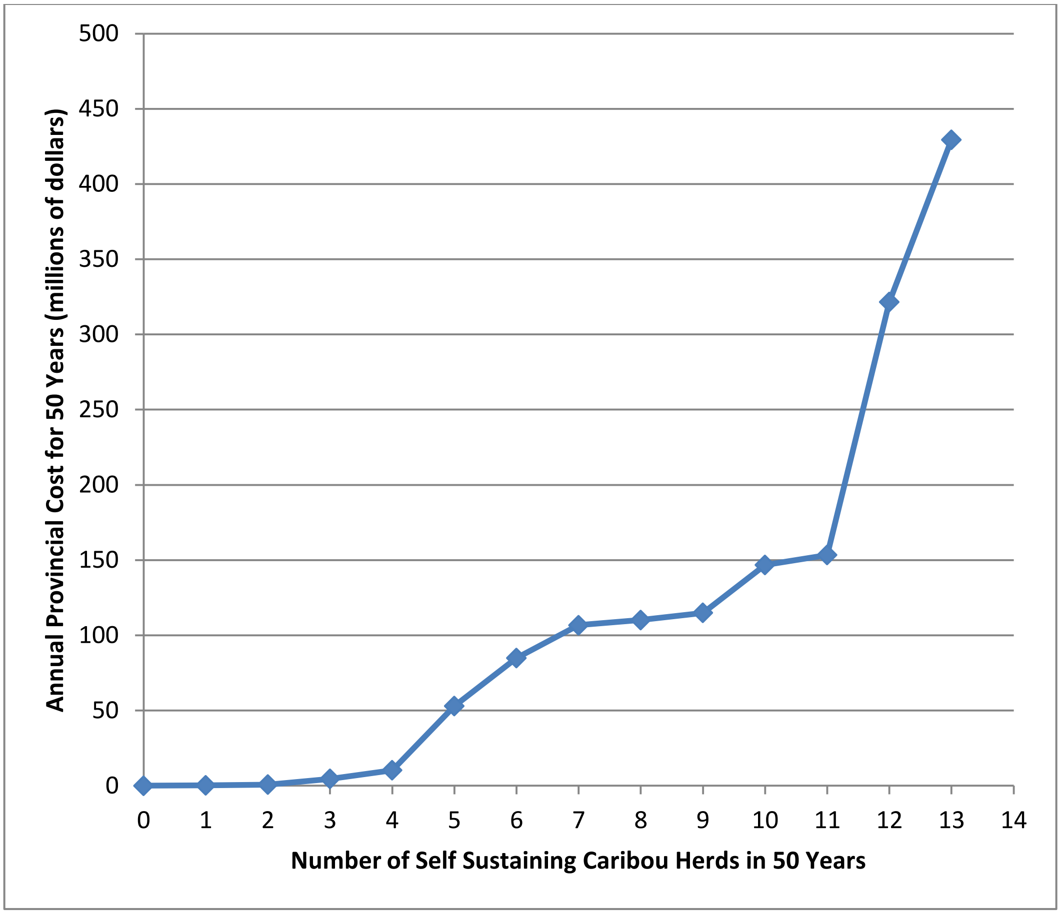
	Very important	Moderately important	A little important	Not at all important
Help recover caribou populations				
Protect old growth stands of boreal forest				
Protect other natural resources				

14. What is the **minimum number** of self-sustaining caribou herds (there are 14 caribou herds in the province of Alberta), 50 years from now, that your household would find acceptable? ________

15. If caribou conservation requires additional tax funds, what is the **maximum annual increase in taxes** your household would find acceptable for the next 50 years? $________

SECTION 7: CONSIDERING CARIBOU CONSERVATION OPTIONS

Conserving woodland caribou habitat will reduce economic development and provincial royalty and tax revenues. Since these decisions involve public resources – caribou and provincial revenues – we are asking for your opinion concerning what level of conservation action to engage in. The following graphs represent the “tradeoff” between different levels of caribou conservation and economic development.

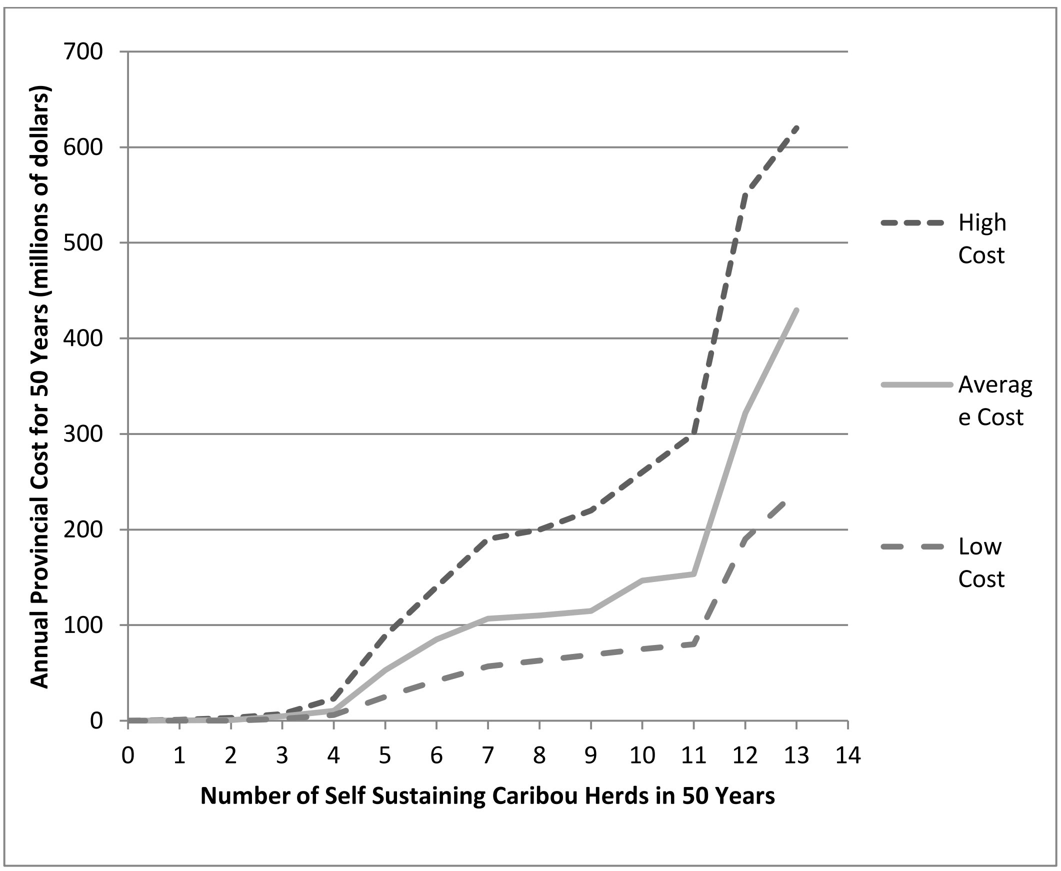


The **horizontal axis** represents the results of different conservation strategies that could ensure that some or up to all 14 of Alberta's caribou herds are "self-sustaining" or which have populations that can be maintained **over the next 50 years and beyond** on their own. These self-sustaining herds are nearly certain to be not at risk. Herds not selected for conservation, including those outside of Alberta, may still have caribou, but the chances of their survival are uncertain.

The **vertical axis** is the cost of achieving these caribou conservation levels, measured as the cost to the province per year in millions of dollars. The costs include management activities as well as taxes and royalties foregone from the energy and forestry sectors. These costs represent the amount the province of

Alberta will be required to pay in order to maintain funding of public programs at current levels. This amount would be paid **each year for the next 50 years from now**.

Each point along the curves represents the minimum cost that will achieve a certain conservation objective. Notice that the curve increases slowly at first. This means that the costs of conserving the first few caribou herds are relatively low. As the conservation objective increases to allow for more caribou, the costs begin to rise.



These curves have been calculated using the best available information. They represent the best estimates we have of the actual costs associated with the conservation objectives.

There are various sources of uncertainty which are inherent when calculating costs and predicting conservation objectives. However, the largest source of uncertainty is in determining the costs. The costs associated with caribou conservation will vary depending on:

- Prices of oil, gas and forest products
- Costs of energy and forestry extraction
- Development of new technologies for energy and forestry extraction

The curves presented above shows the provincial costs for three different estimates of what energy prices will be in the future: the dashed line is based on low energy price forecasts, the solid line on medium or average price forecasts and the dotted line on high price forecasts.

SECTION 8: VOTES

We would like your opinion on the **"tradeoff"** between caribou conservation objectives and economic costs.

The next series of questions asks you to compare the **current management strategy** in Alberta with different scenarios (**proposed management strategy**) about what **could** happen **within the next 50 years** if additional efforts were undertaken to protect woodland caribou habitat.

These scenarios will vary in terms of the following characteristics:

- Our best estimate of your household's annual cost for the program, which depends on energy prices and other factors
- Number of caribou herds which are self-sustaining

We are asking you to state whether you feel that the conservation program, for the amount of money per household per year that the program will cost, should be undertaken.

After analyzing the differences between the current management strategy and the proposed management strategy, you will be asked to "vote" for or against the proposed strategy.

Some people might choose to vote to keep the current management strategy because they think:

- The proposed management strategy costs too much money for the improvement in caribou population
- There are other things, including other environmental protection options, where my money would be better spent

Other people might choose one of the proposed management strategy options because they think:

- The improvement in caribou populations is worth the money
- This is a good use of money compared to other things provincial government money could be spent on

PLEASE NOTE:

We know that how people vote on a survey is often not a reliable indication of how people would actually vote at the polls. In surveys, some people ignore the monetary and other sacrifices they would really have to make if their vote won a majority and became law. We call this hypothetical bias. In surveys that ask people if they would pay more for certain services, research has found that people may say that they would pay 50% more than they actually will in real transactions.

It is very important that you "vote" as if this were a real vote. You need to imagine that you actually have to dig into your household budget and pay the additional costs associated with the program.

You will now vote 2 times. Choose ONLY ONE OPTION for each question. Assume that the options presented for EACH QUESTION are the ONLY ones available. Each time, please vote INDEPENDENTLY from the other votes – do not compare options from different questions.

VOTE 1: Suppose you were asked to consider the proposed management strategy versus maintaining the current management strategy as described below.

	Current Management Strategy	Proposed Management Strategy
Number of self-sustaining caribou herds *in 50 years*	2	10
Your household's share of the cost *per year for the next 50 years* in provincial income taxes	$0	$75

VOTE 1. Please carefully compare the two alternatives presented in the table above. If you had to VOTE on these two options, which one would you choose?

PLEASE CHECK ONE RESPONSE ONLY

- ❑ CURRENT management strategy
- ❑ PROPOSED management strategy

1a. How certain are you that this is the choice you would make if this was an actual referendum? PLEASE CHECK ONE RESPONSE ONLY

- ❑ Very Certain
- ❑ Somewhat Certain
- ❑ Neither Certain nor Uncertain
- ❑ Somewhat Uncertain
- ❑ Very Uncertain

1b. What percent of Alberta residents do you think would vote for the **PROPOSED** management strategy specified above? _______%

1c. Please provide any comments that might help us understand why you voted the way you did.

____

____

16. When choosing between the CURRENT management strategy and the PROPOSED management strategy, how important was each of the following to you?

PLEASE CHECK ONE RESPONSE FOR EACH STATEMENT

	Not at all important	Somewhat important	Very important	Extremely important
Number of self-sustaining caribou herds in 50 years				
Your household's share of the cost per year for the next 50 years in provincial income taxes				

17. When I voted to keep the CURRENT management strategy in at least one of the votes above it was because… (PLEASE CHECK ALL THAT APPLY)

- ❑ I believe that is too much money for the associated improvement in caribou populations
- ❑ There are other things, including other environmental protection options, where my money would be better spent
- ❑ I do not believe the proposed management strategy will actually generate the improvements in caribou populations
- ❑ I do not have enough information to make this decision
- ❑ Other reason: (PLEASE SPECIFY)
  ____

18. When I voted for the PROPOSED management strategy in at least one of the votes above it was because…

PLEASE CHECK ALL THAT APPLY

- ❑ The improvement in caribou populations is worth the money
- ❑ We should pay whatever it takes to conserve caribou populations
- ❑ This is a good use of money compared to other things provincial government money could be spent on
- ❑ I believe the proposed management strategy will actually generate the improvements in caribou populations
- ❑ Other reason: (PLEASE SPECIFY) ____

In some cases, the Species at Risk legislation requires management action that will be costly. However, the cost will also be related to the conservation outcome. Suppose you were asked to consider two management strategies, Management Strategy A and Management Strategy B, as described below. Please assume that these are the only two management strategies available.

	Management Strategy A	Management Strategy B
Number of self-sustaining caribou herds *in 50 years*	9	6
Your household's share of the cost *per year for the next 50 years* in provincial income taxes	$92	$68

CHOICE 2. Please carefully compare the two management strategies presented in the table above. If you had to choose one of these strategies, would you choose Management Strategy A or Management Strategy B?

PLEASE CHECK ONE RESPONSE ONLY

- ❑ Management Strategy A
- ❑ Management Strategy B

2a. How certain are you that this is the choice you would make if this was an actual decision?

- ❑ Very Certain
- ❑ Somewhat Certain
- ❑ Neither Certain nor Uncertain
- ❑ Somewhat Uncertain
- ❑ Very Uncertain

2b. What percent of Alberta residents do you think would choose **Management Strategy A** as specified above? _______%

2c. Please provide any comments that might help us understand why you chose the strategy you did.

____

____

19. When choosing between Management Strategy A and Management Strategy B, how important was each of the following to you?

PLEASE CHECK ONE RESPONSE FOR EACH STATEMENT

	Not at all important	Somewhat important	Very important	Extremely important
Number of self-sustaining caribou herds in 50 years				
Your household's share of the cost per year for the next 50 years in provincial income taxes				

20. If you chose **Management Strategy A** in the choice above it was because…

PLEASE CHECK ALL THAT APPLY

- ❑ The improvement in caribou populations is worth the money
- ❑ This is a good use of money compared to other things provincial government money could be spent on
- ❑ I believe the proposed management strategy will actually generate the improvements in caribou populations
- ❑ We should pay whatever it takes to conserve caribou populations
- ❑ Other reason: (PLEASE SPECIFY)
  ____

21. If you chose **Management Strategy B** in the choice above it was because…

PLEASE CHECK ALL THAT APPLY

- ❑ I believe that **Management Strategy A** costs too much money for the associated improvement in caribou populations
- ❑ There are other things, including other environmental protection options, where my money would be better spent
- ❑ I do not believe the proposed management strategy will actually generate the improvements in caribou populations
- ❑ I do not have enough information to make this decision
- ❑ Other reason: (PLEASE SPECIFY) ____

22. How certain do you think scientists are about the status of caribou populations (threatened, at risk)?

- ❑ Very Certain
- ❑ Somewhat Certain
- ❑ Neither Certain nor Uncertain
- ❑ Somewhat Uncertain
- ❑ Very Uncertain

23. Did it seem to you that it would take a lot more than 50 years or a lot less than 50 years for the proposed changes in the caribou herds to occur?

- ❑ A lot more
- ❑ A lot less
- ❑ Not sure

24. Do you feel your responses will have an impact on the policy decisions for caribou conservation?

- ❑ Yes
- ❑ No
- ❑ Not sure

25. To what extent do you believe that your choices will be used by policy makers?

- ❑ Not at all
- ❑ Weakly
- ❑ Moderately
- ❑ Strongly

SECTION 9: OTHER INFORMATION

We just have a final few questions. Please be assured this information will only be used to report comparisons among groups of people. Your identity will not be linked to your responses in any way.

23. Are you…?

- ❑ Male
- ❑ Female

24. In what year were you born? ________

25. Do you live in a city or town that has more than 1,000 people?

- ❑ Yes
- ❑ No

26. How many people live in your household including yourself? ________

27. How many years have you lived in Alberta? ________

28. What is your marital status?

- ❑ Single
- ❑ Married
- ❑ Common law

29. What is your postal code? _______

30. Which of the following is the highest level of education you have completed?

- ❑ Grade school or some high school
- ❑ Completed high school
- ❑ Post-secondary technical school
- ❑ Some university or college
- ❑ Completed college diploma
- ❑ Completed university undergraduate degree
- ❑ Completed post-graduate degree (masters or Ph.D.)

31. What is your current employment status?

- ❑ Working full time outside the home or self employed
- ❑ Working part time outside the home or self employed
- ❑ Student
- ❑ Homemaker
- ❑ Retired
- ❑ Unemployed

32. Which sector are you employed in?

- ❑ Agriculture
- ❑ Forestry, fishing, mining, oil and gas
- ❑ Utilities, construction and manufacturing
- ❑ Transportation and warehousing
- ❑ Finance, insurance, real estate and leasing
- ❑ Educational services

- ❑ Health care and social assistance
- ❑ Information, culture and recreation
- ❑ Accommodation and food services
- ❑ Public administration
- ❑ Other

33. Are you a member of or associated with any environmental organization (e.g., Greenpeace, Sierra Club, etc.)?

- ❑ Yes
- ❑ No

34. In which of the following activities have you participated in the past 12 months?

PLEASE CHECK ALL THAT APPLY

- ❑ Camping
- ❑ Hiking
- ❑ Cross-country/downhill skiing
- ❑ Wildlife viewing
- ❑ Sightseeing in natural areas
- ❑ Ecotourism (paid visits for nature viewing)
- ❑ Photographing nature
- ❑ Fishing
- ❑ Hunting
- ❑ None of the above

35. How often do you personally watch television programs about animals and birds in the wild?

- ❑ Very often
- ❑ Often
- ❑ Sometimes
- ❑ Rarely
- ❑ Never

36. How often do people in your household eat wild meat?

- ❑ Very often
- ❑ Often
- ❑ Sometimes
- ❑ Rarely
- ❑ Never

37. Which category best describes your total household income (before taxes) in 2009?

- ❑ Less than $10,000
- ❑ $10,000 - $19,999
- ❑ $20,000 - $29,999
- ❑ $30,000 - $39,999
- ❑ $40,000 - $49,999
- ❑ $50,000 - $59,999
- ❑ $60,000 - $69,999
- ❑ $70,000 - $79,999
- ❑ $80,000 - $89,999
- ❑ $90,000 - $99,999
- ❑ Over $100,000

THANK YOU VERY MUCH FOR YOUR COOPERATION

APPENDIX – SPECIES AT RISK DEFINITIONS

Definitions of General Status Categories for Canada (COSEWIC 2001)

Risk Category	Definition
Extinct (X)	A species that is no longer found anywhere in the world.
Extirpated (XT)	A species that is no longer found in an area where it used to live but remains in the wild somewhere else in the world.

Endangered (E)	A species that may become extirpated or extinct.
Threatened (T)	A species that may become endangered.
Special Concern (SC)	A species that has characteristics which make it particularly sensitive to human activities or natural events.
Not At Risk (NAR)	A species that has been evaluated and found to be not at risk.
Data Deficient (DD)	A species for which there is insufficient scientific information to support status designation.

REFERENCES

Alberta Sustainable Resource Development and Alberta Conservation Association. 2010. Status of the Woodland Caribou (Rangifer tarandus caribou) in Alberta: Update 2010. Alberta Sustainable Resource Development. Wildlife Status Report No. 30 (Update 2010). Edmonton, AB. 88 pp.

COSEWIC. 2001. Canadian Species at Risk. Found online at http://www.sararegistry.gc.ca/virtual_sara/ files/species/clwsa_0501_e.pdf [Assessed June 7, 2010]

COSEWIC. 2002. COSEWIC assessment and update status report on the woodland caribou *Rangifer tarandus caribou* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xi + 98 pp

Schneider RR, Hauer G, Adamowicz WL and S Boutin. 2009. Triage for conserving populations of threatened species: The case of woodland caribou in Alberta. *Biological Conservation* 143, 7: 1603-1611

Statistics Canada. No date. Table 385-0002 Federal, provincial and territorial general government revenue and expenditures, for fiscal year ending March 31, annual (dollars), terminated, data in millions (table). CANSIM (database). Using E-STAT (distributor). Last updated August 27, 2009. http://estat.statcan.gc.ca/cgi-win/CNSMCGI.EXE (accessed October 25, 2010).

For more information you may visit the following web sites:
http://www.srd.alberta.ca/

http://www.albertacariboucommittee.ca/

6.3 APPENDIX 3: ADDITIONAL ENDOGENEOUS CUTOFF MODELS

6.3.1 Appendix 3.1: Estimation results of endogenous cutoff model with herd cutoff

MODEL	CEL1	CEL2	CEL3	CEL4
UTILITY FUNCTION - ATTRIBUTES				
ASC – Status quo	**-0.177 (0.083)**	-0.129 (0.216)	-0.187 (0.171)	-0.092 (0.214)
Herd	-0.002 (0.029)	0.065 (0.051)	0.002 (0.021)	**0.08 (0.045)**
Bid ($10)	**-0.03 (0.004)**	**-0.026 (0.007)**	**-0.031 (0.003)**	**-0.021 (0.007)**
UTILITY FUNCTION - INTERACTIONS				
Herd x Age		**-0.004 (0.001)**		**-0.004 (0.001)**
Herd x Years living in Alberta		**0.003 (0.001)**		**0.003 (0.001)**
Bid x Years living in Alberta		**-0.001 (0)**		**-0.001 (0)**
Bid x full-time work		**0.02 (0.005)**		**0.01 (0.006)**
UTILITY FUNCTION - PENALTY ON CUTOFF VIOLATIONS				
Herd	**-0.144 (0.044)**	**-0.161 (0.059)**	**-0.21 (0.042)**	**-0.223 (0.052)**
HERD CUTOFF FUNCTION				
Constant	**1.882 (0.141)**	**1.909 (0.113)**	**0.95 (0.248)**	**1.108 (0.205)**
Fulltime work			**0.531 (0.145)**	**0.36 (0.139)**
Watch TV programs about animal			0.164 (0.118)	0.123 (0.099)
Hunter			**0.722 (0.18)**	**0.465 (0.164)**
Urban			**0.38 (0.165)**	**0.325 (0.135)**
Log-likelihood	-597.238	-575.762	-583.936	-570.126
Rho-square	0.099	0.131	0.119	0.14
Mean of estimated herd cutoff	6.56	6.75	5.49	5.21

Note: Coefficients in bold are significant at 10%. The last column presents direct Poisson regressions (right-censored for the case of herd cutoff) of stated cutoffs on individual characteristics.

6.3.2 Appendix 3.2: Estimation results of endogenous cutoff model with 4-category herd cutoff

MODEL	CEL1	CEL2	CEL3	CEL4
UTILITY FUNCTION - ATTRIBUTES				
ASC – Status quo	**-0.491 (0.159)**	**-0.482 (0.193)**	**-0.572 (0.169)**	**-0.524 (0.171)**
Herd	-0.023 (0.037)	0.05 (0.068)	0.006 (0.021)	0.051 (0.047)
Bid ($10)	**-0.032 (0.004)**	**-0.026 (0.007)**	**-0.035 (0.003)**	**-0.023 (0.007)**
UTILITY FUNCTION - INTERACTIONS				
Herd x Age		**-0.004 (0.001)**		**-0.004 (0.001)**
Herd x Years living in Alberta		**0.004 (0.001)**		**0.003 (0.001)**
Bid x Years living in Alberta		**-0.001 (0.0002)**		**-0.001 (0.0002)**
Bid x full-time work		**0.02 (0.005)**		**0.015 (0.006)**
UTILITY FUNCTION - PENALTY ON CUTOFF VIOLATIONS				
Herd	**-0.834 (0.155)**	**-0.829 (0.322)**	**-3.137 (0.73)**	**-0.764 (0.263)**
HERD CUTOFF FUNCTION				
Constant	**0.779 (0.111)**	**0.779 (0.092)**	-0.112 (0.114)	0.169 (0.265)
Fulltime work			**0.287 (0.076)**	0.171 (0.104)
Watch TV programs about animal			0.095 (0.067)	0.121 (0.107)
Hunter			**0.273 (0.083)**	**0.548 (0.225)**
Urban			0.15 (0.096)	**0.524 (0.265)**
Log-likelihood	-596.672	-575.538	580.358	-571.923
Rho-square	0.1	0.131	0.124	0.137
Mean of estimated herd cutoff (herds)	6-7	6-7	3-4	6-7

Note: Coefficients in bold are significant at 10%. The last column presents direct Poisson regressions (right-censored for the case of herd cutoff) of stated cutoffs on individual characteristics. In these models, herd cutoff has four categories: 1: 0-3 herds; 2: 3-6 herds; 3: 6-10 herds; 4: more than 10 herds.

6.4 APPENDIX 4: EXPERIMENT SCRIPT AND QUESTIONNAIRE OF HARRISION *ET AL*. (2005)

WELCOME TO THE EXPERIMENT

THESE ARE YOUR INSTRUCTIONS

This is an experiment in the economics of decision making. Your participation in this experiment is voluntary. However, we think you will find the experiment interesting, you will be paid for your participation *and* you could make a considerable amount of additional money. The instructions are simple and you will benefit from following them carefully. Please take a few minutes to read them through.

In this experiment you may receive some money from us. How much you receive will depend partly on chance and partly on the choice you make in a decision-problem which you will be asked.

The problems are not designed to test you. What we want to know is what choices you would make in them. The only right answer is what you really would choose. That is why the problems give you the chance of winning real money.

The experiment will proceed in two parts.

The first part consists of some questions about yourself. This information is for our records only. These questions will be given to you using the computer. The rest of the experiment is given to you using paper and pen. The published results of our research will not identify any individual or the choice he or she made in any way. Nor will we give this information to anyone in any other way.

The second part is a description of a decision problem in which chance may play a part. Your decision-problem requires you to make a choice between two options. This is described in more detail below.

At this time we ask that you answer the questions that will be presented to you on the computer screen.

We will now continue with the second part of the experiment. Your decision sheet shows ten decisions listed on the left. Each decision is a paired choice between "Option A" and "Option B." You will make ten choices and record these in the final column, but only one of them will be used in the end to determine your earnings. Before you start making your ten choices, please let me explain how these choices will affect your earnings.

Here is a ten-sided die that will be used to determine payoffs. The faces are numbered from 1 to 10, since the 0 face of the die will serve as 10. After you have made all of your choices, we will throw this die twice, once to select one of the ten decisions to be used, and a second time to determine what your payoff is for the option you chose, A or B, for the particular decision selected. Even though you will make ten decisions, only one of these will end up affecting your earnings, but you will not know in advance which decision will be used.

Obviously, each decision has an equal chance of being used in the end.

Now, please look at Decision 1 at the top. Option A pays $2.00 if the throw of the ten sided die is 1, and it pays $1.60 if the throw is 2-10.

Option B yields $3.85 if the throw of the die is 1, and it pays $0.10 if the throw is 2-10. The other Decisions are similar, except that as you move down the table, the chances of the higher payoff for each option increase. In fact, for Decision 10 in the bottom row, the die will not be needed since each option pays the highest payoff for sure, so your choice here is between $2.00 or $3.85.

To summarize, you will make ten choices: for each decision row you will have to choose between Option A and Option B. You may choose A for some decision rows and B for other rows, and you may change your decisions and make them in any order. Remember, you will only be paid for one of these rows, which will be randomly selected. When you are finished, we will come to your desk and throw the ten-sided die to select which of the ten Decisions will be used. Then we will throw the die again to determine your money earnings for the Option you chose for that Decision. Earnings for this choice will be added to your show-up fee of $5.

So now please look at the empty boxes on the right side of the record sheet. You will have to write a decision, A or B in each of these boxes, and then the die throw will determine which one is going to count. We will look at the decision that you made for the choice that counts, and circle it, before throwing the die again to determine your earnings for this part. Then you will write your earnings in the blank at the bottom of the page.

Are there any questions?

ID: _______________

Some Questions About You

In this survey most of the questions asked are descriptive. We will not be grading your answers and your responses are completely confidential. Please think carefully about each question and give your best answers.

1. What is your AGE? _____________ years

2. What is your sex? (Circle one number.)

01 Male 02 Female

3. Which of the following categories best describes you? (Circle one number.)

01	White	06	Hispanic-American
02	African-American	07	Hispanic
03	African	08	Mixed Race
04	Asian-American	09	Other
05	Asian		

4. What is your major? (Circle one number.)

01 Accounting

02 Economics

03 Finance

04 Business Administration, other than Accounting, Economics, or Finance

05 Education

06 Engineering

07 Health Professions

08 Public Affairs or Social Services

09 Biological Sciences

10 Math, Computer Sciences, or Physical Sciences

11 Social Sciences or History

12 Humanities

13 Psychology

14 Other Fields

5. What is your class standing? (Circle one number.)

01	Freshman	04	Senior
02	Sophomore	05	Masters
03	Junior	06	Doctoral

6. What is the **highest** level of education you expect to **complete**? (Circle one number)

    01 Bachelor's degree

    02 Master's degree

    03 Doctoral degree

    04 First professional degree

7. What was the highest level of education that your **father** (or male guardian) **completed**? (Circle one number)

    01 Less than high school

    02 GED or High School Equivalency

    03 High school

    04 Vocational or trade school

    05 College or university

8. What was the highest level of education that your **mother** (or female guardian) **completed**? (Circle one number)

    01 Less than high school

    02 GED or High School Equivalency

    03 High School

    04 Vocational or trade school

    05 College or university

9. What is your citizenship status in the United States?

    01 U.S. Citizen

    02 Resident Alien

    03 Non-Resident Alien

    04 Other Status

10. Are you a foreign student on a Student Visa?

01 Yes

02 No

11. Are you currently...

01 Single and never married?

02 Married?

03 Separated, divorced or widowed?

12. On a 4-point scale, what is your current GPA if you are doing a Bachelor's degree, or what was it when you did a Bachelor's degree? This GPA should refer to all of your coursework, not just the current year. Please pick one:

01 Between 3.75 and 4.0 GPA (mostly A's)

02 Between 3.25 and 3.74 GPA (about half A's and half B's)

03 Between 2.75 and 3.24 GPA (mostly B's)

04 Between 2.25 and 2.74 GPA (about half B's and half C's)

05 Between 1.75 and 2.24 GPA (mostly C's)

06 Between 1.25 and 1.74 GPA (about half C's and half D's)

07 Less than 1.25 (mostly D's or below)

08 Have not taken courses for which grades are given.

13. How many people live in your household? Include yourself, your spouse and any dependents. Do not include your parents or roommates unless you claim them as dependents.

____

14. Please circle the category below that describes the total amount of INCOME earned in 2001 by the people in your household (as "household" is defined in question 13).

[Consider all forms of income, including salaries, tips, interest and dividend payments, scholarship support, student loans, parental support, social security, alimony, and child support, and others.]

01 $15,000 or under

02 $15,001 - $25,000

03 $25,001 - $35,000

04 $35,001 - $50,000

05 $50,001 - $65,000

06 $65,001 - $80,000

07 $80,001 - $100,000

08 over $100,000

15. Please circle the category below that describes the total amount of INCOME earned in 2001 by your parents. [Consider all forms of income, including salaries, tips, interest and dividend payments, social security, alimony, and child support, and others.]

01 $15,000 or under

02 $15,001 - $25,000

03 $25,001 - $35,000

04 $35,001 - $50,000

05 $50,001 - $65,000

06 $65,001 - $80,000

07 $80,001 - $100,000

08 over $100,000

09 Don't Know

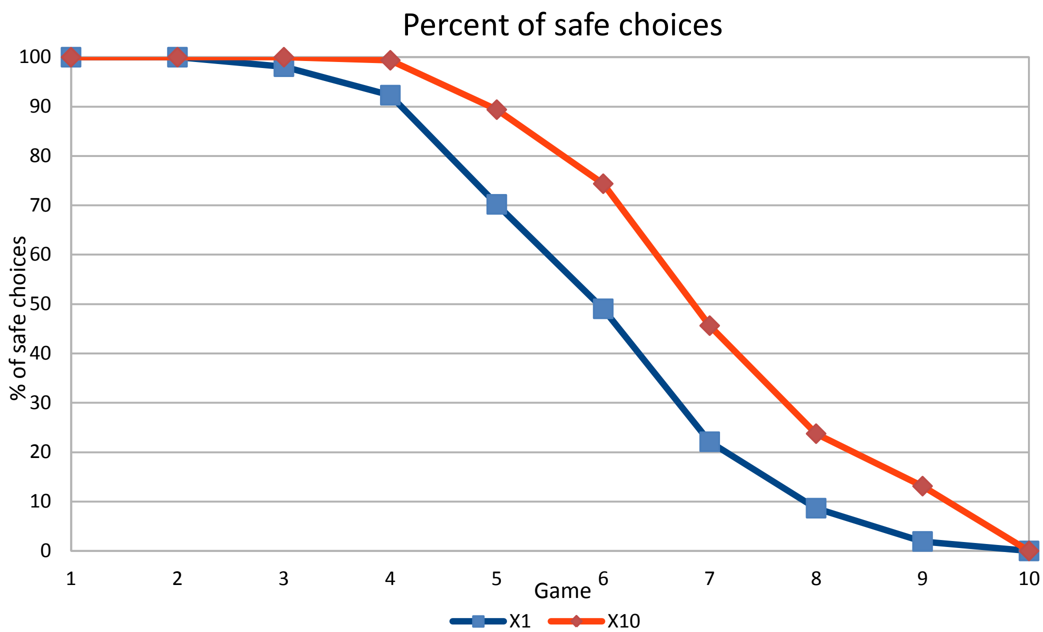
16. Do you currently smoke cigarettes? (Circle one number.)

00 No

01 Yes

If yes, approximately how much do you smoke in one day? _______ packs

6.5 APPENDIX 5: STATISTICS OF HARRISON *ET AL*. (2005) DATA



Statistics of variables used

	Mean	Std dev	Min	Max
Age	21.19	4.09	17	49
Student group	**Frequency**	**%**		
Freshman	29	18%		
Sophomore	39	24%		
Junior	33	20%		
Senior	30	19%		
Graduate	31	19%		
GPA	**Frequency**	**%**		
Low	51	31%		
Average	67	41%		
High	44	27%		
Other dummy variables	**Frequency of 1**	**% of total**		
Business	72	44.44%		
Black	32	19.75%		
Edexpect	40	24.69%		
Edfather	104	64.20%		
Edmother	85	52.47%		
Female	88	54.32%		
US citizen	132	81.48%		

Note: BUSINESS: major is in business; EDEXPECT: expect to finish a Ph.D. or Professional degree; GPAHI: GPA > 3.75; GPALOW: GPA < 3.24; EDFATHER: father completed college; EDMOTHER: mother completed college; SOPHOMORE, JUNIOR, SENIOR and GRADUATE indicates student type; ORDER: played a previous game session; USCITIZEN: U.S. citizen.