

Valuing Non-market Goods: Three Essays on Outdoor Recreation

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DEDICATION

I would like to dedicate this dissertation to my late grandparents who passed away during my PhD. This work is also dedicated to my parents who encourage and support me throughout my academic career.

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ABSTRACT

Millions of people annually participate in a variety of nature-based outdoor activities on public lands. While the recreation spending these people bring to an area is helpful in characterizing the economic contribution of recreation activities in the local economy, the total value of many natural resource amenities for recreational use is not fully understood. This is mainly because of the non-market nature of natural resource amenities, which often lack market data to characterize the monetary value. Revealed preference non-market valuation methods such as travel cost modeling allow modeling demand for access to sites of recreational potential with respect to cost of travel and thereby estimate the economic value of site access. The essays included in this dissertation utilize methods grounded in travel cost theory to address three unique problems related to economic valuation of outdoor recreation resources.

This first essay employs an individual travel cost model with onsite survey data of national forests visitors to investigate the economic value of downhill skiing. The model is extended to project the potential effects of climate change on demand and value of downhill skiing in the foreseeable future. The second essay applies a similar valuation framework on nationwide visitor survey data to assess and compare the demand for and value of non-motorized boating access between Wild and Scenic Rivers designated and non-designated rivers. Although no significant difference exists between designated and non-designated rivers, the findings of this study underscore the importance of various site characteristics in recreational value. The third essay utilizes a zonal travel cost model of hunting permit application to address a unique issue of valuation in the presence of lottery-rationed demand. Specific findings incorporated in

these three essays and the overall conclusions drawn from these studies will help resource managers, and planners understand the net benefit and public value of nature-based recreation resources and guide in management and policy making.

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CHAPTER 1

INTRODUCTION

1.1 Background

In the United States, millions of people annually participate in some form of outdoor recreation (Bowker et al., 2012; Cordell et al. 2012; White et al., 2016). These recreationists help grow the economy by bringing in expenditures and creating jobs in rural communities. The outdoor recreation industry is expected to continue growing in the future, as participation in many activities is projected to increase. Even though the participation rate is expected to decrease in many activities, total participation will continue to increase due to population growth (Bowker et al. 2012; Cordell et al. 2012).

The Outdoor Industry Association [OIA] (2017) reported that the industry is one of the nation's largest economic sectors with expenditures of \$887 billion, 7.6 million jobs, and \$125 billion in tax revenue (federal, state and local) generated from outdoor recreation activities. With the ripple effect on the economy, the outdoor recreation industry has an impact of \$1.6 trillion and creates 12 million jobs (USDA Forest Service, 2018). Out of the total expenditures, about \$184 billion is spent on outdoor recreation products such as gear, equipment, services, and vehicle purchase, and about \$702 billion is spent travel expenditures including airfare, fuel, lodging, guide and lift tickets, and lessons.

The expenditures show only part of the benefits that recreationists receive from services, and past studies commonly used economic impact assessment to analyze the impact of recreation on the economy through employment and income by employing input-output analysis. The cost-benefit analysis used in evaluating management alternative often does not include non-market

values of natural resources that provide recreational opportunities. Bergstrom and Cordell (1991) estimated the net economic value of 37 different outdoor recreation activities in the United States. They reported a net economic value of \$271.94 billion annually (2018 dollars) which shows the enormity of the net economic benefits of recreational services provided by natural resources and warrants in-depth investigation into the demand and net benefit of natural resource use for recreation propose.

1.2 Problem statement

The recreation demand modelling offers the relationship between human behavior and the environment (Hanley, Iwata, & McCord, 2003). As outdoor recreation activities are based on natural resources, increasing recreation demand brings adverse impacts on the limited natural resources such as overuse and environmental impact. Since public lands offer a variety of ecosystem services, the management decision about public lands may not be optimal without proper valuation and accounting of all uses of such services. Characterizing total value, including both marketed and non-marketed benefits, can guide decisions regarding efficient management of resource for recreation (Duffus & Dearden, 1990).

Non-marketed value of goods or services such as outdoor recreation access are not typically traded in the market, and therefore are difficult to quantify. The economic value of recreation access to the natural resource can be estimated regarding how much an individual is willing to pay to access such opportunities or how much they are willing to accept to give it up. While a variety of non-market valuation methods that are grounded in economic theory have

been developed and tested, each case of valuation presents a unique challenge for the researcher and often requires refining modeling assumptions and estimation techniques. On the other hand, a variety of factors related to the nature and condition of resource system itself (e.g. water quality, accessibility), socio-demographic attributes of the recreationists, climatic conditions (e.g. temperature, snowfall, precipitation), legal and political circumstances may directly or indirectly influence recreation demand and quality of recreation experience.

One of the many factors that may directly or indirectly influence outdoor recreation is climate change. Although most outdoor recreation activities are more or less affected by climatic factors, winter sports such as downhill skiing are considered more vulnerable to changing climatic conditions. The climate change can impact skiing in many ways such as reducing the natural availability of snow, shortening the season, and hindering the snowmaking capacity of the resorts (Gilaberte-Búrdalo, López-Martín, Pino-Otín, & López-Moreno, 2014). These conditions could affect the overall recreational experience of the skiers. Previous models of ski participation and trip demand have either failed to account for climatic factors or used climate data of recreationists' residence (rather than the destination) (Bergstrom & Cordell, 1991; Bowker et al., 2009). Many of those studies have relied on a smaller sample (single ski resort, national forest) and have limited generalizability. To fill this gap in literature, there is a need for developing a comprehensive model of skiing trip demand by incorporating climate-related variables in classical travel cost model to evaluate the effect of expected changes in climatic conditions on ski demand.

Many regulations and policies have been promulgated to conserve and to manage the natural resources. The Wild and Scenic Rivers Act is one of the policies to protect a river or section of the rivers with outstanding scenic, recreational, and cultural values in a free-flowing condition for the benefits of present and future generation. Congressional designation of publicly managed river systems involves substantial investment of public funding and foregone opportunity cost. Therefore, understanding whether and how such designations lead to increased net benefit for recreationists accessing these rivers for permitted use becomes a question of high policy interest in natural resource management.

Similarly, recreation sites facing growing visitation can experience impacts on the natural integrity of the physical environment and the quality of the visitors' recreation experience (Nickerson, 1990). Resource managers often restrict access to regulate recreation activities to achieve a balance between conservation and use. In wildlife management, permits or quota hunt system are typically used to regulate access to big game hunting (Scrogin et al., 2003; Reeling et al., 2016). Existing methods of non-market valuation to model recreation demand primarily rely on trip data, which are often not practical in lottery-rationed recreation demand. Therefore, modification of existing valuation techniques with alternative indicators of recreation demand could benefit wildlife managers and recreation planners in evaluating the public value of access-controlled recreation sites.

The essays incorporated in this dissertation attempt to address these related but different issues in the valuation of outdoor recreation resources by employing methods grounded on travel cost theory.

1.3 Non-market valuation in outdoor recreation

Although the social and economic benefits from natural resources including outdoor recreation opportunities are widely understood, they are difficult to quantify. Research on outdoor recreation demand is primarily motivated by the need for providing economic value of environmental goods and services to inform policymakers and resource managers (Phaneuf & Smith, 2005). Different valuation methods have been used to quantify non-marketed benefits from natural resources.

In general, these methods are broadly categorized into stated preference and revealed preference methods. In stated preference methods, the value of environmental services is elicited to predefined alternatives in the form of rating, ranking or choice (Boxall et al., 1996) and these methods are generally used to value environmental quality changes by asking individuals their willingness to pay to use the services or their willingness to accept to give up the services. In contrast, revealed preference use observations on actual choices made by an individual to measure their preference. The main advantage of revealed-over stated- preference method is that the analysis is based on actual choices individuals make rather than asking or forcing people to make choices in hypothetical scenarios. In doing so, revealed preference methods help avoid potential bias associated with the hypothetical response (Hicks, 2002). Among the revealed preference methods, the travel cost method (TCM) is commonly used in estimating the net economic value of recreation access (Haab & McConnell, 2002; Parsons, 2003). It is a demand based model for recreational use of a site or multiple sites (Parsons, 2003), in which a number of trips taken by a recreationist is modeled as a function of the cost of accessing the site and other

social and demographic characteristics of the recreationist. It is based on the assumption that the cost of travel is a proxy price for site access (Boxal et al., 1999). In travel cost modeling, the empirical process of estimating net economic benefits involves two steps of the estimation of parameters of the demand function and the calculation of the welfare measure from the estimates parameters (Haab & McConnell 2002, p. 159).

Clawson and Knetsch (1966) first proposed zonal travel cost model with trips per capita from a given origin being an indicator of demand for site use. The individual TCM modeling has been more popular over time with a number of trips by a recreation party being an indicator of demand. Individual models have been more popular in recent years because it allows modeling individual demand and ensures higher statistical efficiency, and avoids the arbitrary nature of zonal definition in the zonal model. Nevertheless, the zonal TCM is also useful in certain situations such as trip data is not available from individual visitors, data is available only for the most recent trip, and only one trip is possible in a year (Loomis et al., 2009). Due to the nature of valuation question in hand, and availability of data, different forms of travel cost modelling have been used in this dissertation. Theoretically, all models are based on the relationship between travel cost to access recreation site and some indicator of demand for site access.

1.4 Objectives

The objectives of the study are as follows:

- a) To assess the potential effects of climate on downhill skiing and snowboarding demand and value at U.S. National Forests

- b) To assess and compare the demand for and value of non-motorized boating access between the Wild and Scenic River designated and non-designated rivers
- c) To estimate the value of elk hunting access using permit application data

The objectives are achieved by employing individual and modified zonal travel cost methods. The data are collected from survey as well as various secondary sources. The background of each research question, relevant literature, problem statement and justification of the research, theoretical and empirical model, results and discussion are presented in each chapter. The following paragraphs provide overviews of each chapter.

1.5 Essay overview

The first essay (Chapter 2) assesses the economic value for accessing downhill skiing and snowboarding at U.S. National Forests and examines the potential effects of climate on demand and economic value of downhill skiing and snowboarding. Annually, millions of recreationists participate in downhill skiing on skiable land in the U.S. National Forest System, making it the second most popular outdoor activity in the system. While the emerging literature on climate science reveals changing climatic conditions in ski areas, the extent of climate change impact on the demand for and economic value of downhill skiing is unknown. Although numerous studies have addressed the economic value of accessing natural areas for downhill skiing, only two travel cost studies have analyzed national level skiing data but they failed to account for climatic factors. By combining trip data collected from on-site surveys of skiers in national forests across the nation with climatic data collected through nearby weather stations, this essay develops an

aggregated travel cost model to estimate the net economic benefit of downhill skiing and snowboarding, and the projected impact of climate change on that demand and value. The per person per trip net economic benefit of downhill skiing and the total economic value of downhill skiing in the U.S. National Forest System by aggregating across visits and national forests is estimated depending on the modeling assumptions about skiers' opportunity cost of time. Climate variables including temperature, snow depth, and rainfall are found to be correlated with ski demand, and projected changes in these climate variables could decrease the economic benefits from skiing. The findings facilitate understanding the net economic benefit of maintaining downhill skiing on public lands in general and national forests in particular and will help recreation planners and tourism entrepreneurs develop adaptive strategies to sustain the skiing industry.

The second essay (Chapter 3) assesses the economic value for accessing non-motorized boating at U.S. National Forests and compares the demand for and economic value of non-motorized boating between Wild and Scenic Rivers (WSR) designated and non-designated rivers. More than half of the rivers currently designated by the U.S. Congress under the Wild and Scenic Rivers Act (WSRA) 1968 are within the system of national forests and grassland. Along with protecting the rivers with outstanding values, these rivers also provide recreation benefits to society. Previous studies have examined these designated rivers in many aspects, but none has assessed the effect of designation on the demand and economic value of recreational access to those rivers for popular activities such as non-motorized boating. Also, there is a lack of reliable estimates of economic value of non-motorized boating that could be generalized to a national

scale. This essay develops an aggregated travel cost model to estimate the net economic benefits of non-motorized boating activities by combining trip data collected from on-site surveys in national forests across the nation with site and river characteristics data. The per person per trip and the total economic benefits of non-motorized boating by aggregating visits across the national forests is estimated depending on the modeling assumption about boaters' opportunity cost of time. However, there is no difference in the demand for and value of non-motorized boating access between designated and non-designated rivers. Further, site characteristics are found to be significantly correlated with demand for non-motorized boating. Results may be useful in enhancing the recreational appeal of rivers for non-motorized boaters and in understanding the value of non-motorized boating on public lands.

The third essay (Chapter 4) estimates the economic value of elk hunting access in Tennessee. The Tennessee Wildlife Resource Agency (TWRA) started elk restoration in the five-county region surrounding the North Cumberland Wildlife Management Area in 2000. As the population started to expand, a quota hunting program was established in 2009 to manage the elk population. While the restoration program is well justified from an ecological perspective, continuous public support for the program requires an understanding of benefit it brings to the region through hunting, wildlife watching, and related activities. This study aims to characterize the economic value of one such service, the opportunity to hunt elk. Due to its non-market nature, the economic benefit of hunting is typically estimated by applying an individual or zonal travel cost model to trip profile data. A trip-based travel cost model is not appropriate in this case, however, because a lottery-rationed hunting permit system dictates hunting opportunities.

To address this issue, this study employs a zonal travel cost approach to model the demand for elk hunting permits, in which permit applications by zip codes are analyzed along with travel cost, and demographics of permit applicants' origins using a count data regression model. The estimated consumer surplus, a monetary measure of expected benefit or the value of opportunity to hunt elk in Tennessee is estimated and then aggregated across zip codes to derive the total benefit of elk hunting in Tennessee. The estimated consumer surplus under different modeling assumptions suggests a substantial value for elk hunting in Tennessee. The results will inform researchers, recreation managers, and policymakers in understanding the public value of elk restoration in Tennessee and similar regions where elk restoration is being considered.

Conclusion and implications of the findings are discussed at the end of the each essay. The final chapter (Chapter 5) of this dissertation summarizes all the key findings from these essays and their policy and management implications.

CHAPTER 2

**POTENTIAL EFFECTS OF CLIMATE ON DOWNHILL SKIING AND
SNOWBOARDING DEMAND AND VALUE AT U.S. NATIONAL
FORESTS**

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Abstract

Annually, 23 million recreationists participate in downhill skiing on more than 180,000 acres of skiable land in the U.S. National Forest System, making it the second most popular outdoor activity in the system. While the emerging literature on climate science reveals changing climatic conditions in ski areas, the extent of climate change impact on the demand for and economic value of downhill skiing is unknown. By combining trip data collected from on-site surveys of skiers in national forests across the nation with climatic data collected through nearby weather stations, this study developed an aggregated travel cost model to estimate the net economic benefit of downhill skiing and snowboarding, and the projected impact of climate change on the demand and value. Per person per trip net economic benefit of downhill skiing was estimated to be in the range of \$91 to \$185 depending on the modeling assumptions about skiers' opportunity cost of time. When aggregated across visits and national forests, the total economic value of downhill skiing in the U.S. National Forest System ranged from \$2.16 to \$4.39 billion, annually. Climate variables including temperature, snow depth, and rainfall were found to be correlated with ski demand, and projected changes in these climate variables could decrease the economic benefits from skiing. Findings are valuable in understanding the net

economic benefit of maintaining downhill skiing on public lands in general and national forests in particular, and will help recreation planners and tourism entrepreneurs develop adaptive strategies to sustain the skiing industry.

2.1 Introduction

Downhill skiing and snowboarding are the most popular winter recreation activities on national forests in the United States. First introduced by the Scandinavian immigrants in the 1830s, the growth and development of downhill skiing accelerated in the 1920s (Briggs, 2000). Skiing has been historically tied to national forests partly because many contain large portions of mountain terrain, an ideal place for skiing (Briggs, 2000). To address the increasing demand for skiing, the U.S. Forest Service (FS) worked with the Civilian Conservation Corps to build winter sports areas, ski trails, small ski lodges, and warming shelters in the 1930s (USDA Forest Service, 2015). The growth of skiing on national forests is partly due to a successful partnership between the FS and privately-owned ski resorts, allowing the commercial businesses to operate on public land, while supervising these businesses to ensure visitor safety and natural resource stewardship (USDA Forest Service, 2015).

The FS currently manages approximately 182,095 acres of skiable lands in 58 national forests where 122 skiing areas operate under special use permit including some of the most iconic resorts in the country (USDA Forest Service, 2016). Out of 470 ski areas operating in the United States (National Ski Areas Association [NSAA], 2014), a little more than one fourth of the ski areas are inside national forests. A recent publication from the FS National Visitor Use

Monitoring (NVUM) program reports that downhill skiing and snowboarding is the second most popular activity in the entire National Forest System (after hiking/walking) with 14.2% of 161 million annual visits listing downhill skiing or snowboarding the primary activity, and 15.1% visits claiming participation in the activity (USDA Forest Service, 2012). Throughout the remainder of the paper, “downhill skiing” is used as a general term for lift accessed downhill skiing and/or snowboarding.

Considering average annual skier and snowboarder visits of 56.5 million in the United States (NSAA, 2016), national forests account for about a 40% share. Skiers typically spend more money per visit than other recreationists on national forests and, as many skiers are non-local, they typically stay in off-forest lodging (USDA Forest Service, 2012). Among the goods and services provided by national forests, ski operations return about \$26 million annually to the U.S. treasury, second only to timber production (USDA Forest Service, 2012). While this indicates the financial return (i.e., revenues) from national forests, it does not fully characterize the total net economic value associated with public access to national forests for downhill skiing.

Numerous studies have addressed the economic value of accessing natural areas for snowsports. However, there are still important gaps pertaining to demand and economic value for downhill skiing, the most popular winter sport in the United States. Utilizing local or regional level data, a few studies have estimated the demand for downhill skiing (Englin & Moeltner, 2004; Hamilton, Brown, & Keim, 2007; Shih, Nicholls, & Holecek, 2009); however, the generalizability of those results is limited because sample sizes were small. Only two travel cost studies have focused on analyzing economic value along with demand for downhill skiing at the

national level (Bergstrom & Cordell, 1991; Bowker et al., 2009), but they failed to account for climatic factors.

To fill this gap in knowledge, this study builds upon previous models of demand for downhill skiing by adding climate-related variables and employing a national-level dataset of skiing participation. Considering the proportion of ski areas and annual number of ski visits in the national forests, the results could be generalized to the national ski industry. The primary research objectives are to estimate the demand for and economic value of downhill skiing in national forests, and to analyze the potential impact of projected climate change on this demand and economic value.

2.2 Previous studies of demand for and value of developed skiing

The travel cost method (TCM) is the most commonly-used revealed preference technique for valuing access to public land for recreational purposes (Bowker et al., 2009). TCM, originally developed by Hotelling (1947) is based on the assumption that the cost incurred in travel to a site can be used to estimate how much one would be willing to pay (WTP) to access the site (Pearse & Holmes, 1993). TCM has been applied in a number of studies to estimate the net economic value of access for a variety of recreational activities such as fishing (Shrestha et al., 2002), rock climbing (Shaw & Jakus, 1996), guided rafting (Bower, English, & Donovan, 1996), camping (Boxall, McFarlane, & Gartrell, 1996), deer hunting (Creel & Loomis, 1990), downhill skiing (Englin & Moeltner, 2004), and boating (Loomis & McTernan, 2014).

Cicchetti, Fisher, and Smith (1976), one of the initial travel cost studies on ski demand, used an aggregate demand equation including travel cost by county to estimate the consumer surplus (CS), a monetary measure of net benefit, associated with the development of a new ski site. They found per trip CS of \$27 (all the CS estimates reported in this paper are in 2016 dollars) for the proposed Mineral King Project in California. Wetzstein and McNeely (1980) used a linear regression model with aggregate cost data collected from on-site interviews in California and Nevada and concluded that 34% of the variation in the number of ski trips is explained by trip cost and distance traveled. In a Colorado study, Morey (1981) analyzed 163 college students trip frequency to 15 ski areas in relation to their ability and socio-economic characteristics. He found that the physical characteristics of the sites, individuals' skiing ability, and the opportunity cost of time accounted for 57% of the variation in trip demand. Walsh and Davitt (1983) employed stepwise regression to analyze the effects of cost per day and other variables such as income, travel distance, substitutes, party size, and ski ability on the length of stay for trips to the Aspen ski resort. The results showed a negative correlation between average cost per day and the length of the stay at the ski site and per trip CS of \$59.

Bergstrom and Cordell (1991) is the first study to estimate national level economic value of downhill skiing which found a CS of \$62 per trip. They used Public Area Recreation Visitors Study (PARVS) data from 200 sites within various public recreation sites. They employed a multi-community, multi-site, zonal travel cost model to develop demand equations and estimate the net economic value of 37 outdoor recreation activities including skiing. Bowker et al. (2009) employed the travel cost method to NVUM's Round 1 data (2000 to 2003) and found per trip net

economic value in the range of \$162 to \$234 for downhill skiing. The net economic benefit or CS from previous studies on downhill skiing are provided in Appendix A.

A few other studies have estimated the demand and economic value of skiing in the United States using alternative approaches. For example, Echelberger and Shafer (1971) estimated the demand for 26 ski resorts in northern New England and New York during 1964-1966 using factor analysis and multiple regression analysis, and found a significant relationship between the number of ski days and travel distance, advertising budget, accessibility, and number of ski instructors available. Johnston and Elsner (1972) also employed multiple regression analysis and estimated a demand function using data from 25 California ski areas for the 1963-64 seasons and found that lift capacity, the length of the season, and substitute distance positively correlated with participant ski days. Using a two-phase regression model, Elsner (1971) found that 69% of the variation in the demand for ski visits was explained by income, education, and occupation.

Other researchers have used alternative valuation methods such as contingent valuation (Walsh, Miller, & Gilliam, 1983) and benefit transfer approach (BTA) (Loomis & Crespi, 1999; Rosenberger & Loomis, 2000) to measure the economic benefits from skiing. For example, Walsh et al. (1983) conducted an on-site survey of skiers in three Colorado ski areas to estimate WTP for lift tickets, contingent on changes in the number of skiers per acre, and found per trip WTP of \$45.

2.3 Effect of climatic factors on developed skiing participation

Climate change is expected to affect many types of outdoor recreation activities in the future (Scott, Jones, & Konopek, 2007a). Gilaberte-Búrdalo, López-Martín, Pino-Otín, and López-Moreno (2014) reviewed the literature on the impact of climate change on the skiing industry and concluded that climate change had significant impacts on skiing by reducing the natural availability of snow, shortening the season, and hindering the snowmaking capacity of resorts. These unfavorable snow conditions could affect the overall quality of the experience during ski trips. While a number of studies have analyzed participation and trip demand for skiing in the United States (Dawson, 2009; Englin & Moeltner, 2004; Hamilton et al., 2007; Moeltner & Englin, 2004; Shih et al., 2009), few studies have assessed the impact of climate factors on skiing demand (Dawson & Scott, 2007; Englin & Moeltner, 2004; Falk, 2013; Shih et al., 2009; Töglhofer, Eigner, & Prettenhaler, 2011). Using daily weather data from two ski resorts in Michigan, Shih et al. (2009) found that temperature, snow depth, and wind chill had a significant impact on ski lift ticket sales suggesting temperature and snow as important factors for ski activity. Töglhofer et al. (2011) examined the impacts of snow conditions on ski demand in 185 Austrian ski areas using time series data from 1972 to 2007 and found a positive relationship between overnight stays and good snow conditions. The effects of weather indices such as days with more than 30cm snow depth, snow depth, and temperature were significant on overnight stays only for areas below 1800m. Although ski areas at higher elevation have more snow and longer ski seasons than at lower elevations (Dawson & Scott, 2013), the effect of climate on ski demand at higher elevation was not significant. Töglhofer et al. (2011) found that

overnight stays at higher elevations were independent of weather variables, at least within the range of their data, and Falk (2010) found that snow depth had a positive effect on overnight stays only for resorts with slopes below 2000m. In relation to the effect of climate change on good skiing conditions, higher elevations are less likely to be vulnerable to climate change than lower elevations (Yohe & Tol, 2002). Falk (2010) also found a similar result in a panel data analysis of overnight stays with respect to snow depth at 28 Austrian ski resorts from 1986 to 2006. Falk (2013) found that domestic tourists were more sensitive to changes in weather conditions than their foreign counterparts. Using daily ski visits from two New Hampshire ski resorts from 1999 to 2006, Hamilton et al. (2007) found that ski visits were more influenced by snowfall in nearby urban areas than at the ski resorts.

The economic sustainability of the skiing industry in the United States is highly dependent on climatic factors. Using nine climate scenarios with varying temperature and precipitation, Mendelsohn and Markowski (1999) projected decreases in revenue from 1990 to 2060 from skiing by as high as \$3.7 billion (51% decrease) and \$4.6 billion (62% decrease) with linear and loglinear demand models, respectively, if temperature increases by 5°C and precipitation increases by 7%. By employing an input-output model of economic activities in the ski industry, Burakowski and Magnusson (2012) estimated a \$1.07 billion loss in aggregate revenue in a low-snowfall year compared to high-snowfall years within a decade (1999-2010). Their projected climate change scenarios for the century showed shortening of season length and decrease in snow depth up to 100%. Englin and Moeltner (2004) applied travel cost method to estimate an empirical demand model for downhill skiing trips by college students in Reno,

Nevada, to 13 ski resorts in the Lake Tahoe area combining behavioral data with climatic data and ski resort characteristics. They estimated per trip CS of \$98 and \$48 for skiers and snowboarders, respectively, and found that ski trips and CS were significantly affected by temperature and snowfall.

2.4 Objective and significance of the study

This paper assesses the effect of climatic factors on the demand for downhill skiing, and it also provides an updated value for downhill skiing. In particular, previous findings have been limited in scope (small sample size, specific study area) or used methods that are arguably less robust compared to the individual TCM. The individual TCM allows modeling individual demand and ensures higher statistical efficiency, and it also avoids the arbitrary nature of zonal definition in the zonal TCM. Englin and Moeltner (2004) is the only study to analyze individual data for the effect of climatic factors on ski trip demand and associated CS, but their findings were based on data from a relatively small and limited sample of 131 college students visiting a few resorts around Reno, Nevada. Although they found significant impacts of climatic factors (temperature, snowfall), further analysis with larger and more representative data could broaden the implications of their findings. While Bowker et al. (2009) applied individual TCM on national level data, they did not consider climate variables in the model and there were some limitation of the NUVM Round 1 data they used for the analysis. Along with including climate variables in the model, this study projects the effect of climate change on ski participation and the economic benefits from downhill skiing in the future.

Downhill skiing relies on climatic conditions to a large extent. However, skiers can alter the destination and timing of their trips or substitute another activity depending on weather conditions (Scott, McBoyle, & Minogue, 2007b). Origin-specific climatic factors are best suited to analyses of local activities such as hiking and fishing which do not typically involve long distance travel, and climatic conditions are likely to be similar at both origin and destination. Activities like skiing often require long distance travel to a site where the climatic conditions are quite different from the traveler's origin. A few studies have used destination-specific data to assess the impact of climatic factors on downhill skiing demand (Dawson & Scott, 2007; Englin & Moeltner, 2004; Shih et al., 2009), but those studies are based on limited data from a few ski destinations. Hence, using destination specific climatic data in combination with trip data collected from a nationwide on-site survey of visitors is another unique feature of this study.

2.5 Methods

2.5.1 Theoretical model

Travel cost analysis assumes that the costs of traveling by an individual or group to the recreation site from their origin are a proxy or shadow price for the value placed on that setting and the opportunities it supports (Boxall, McFarlane, & Gartrell, 1996). Different individuals face different travel costs to a single recreation site or different individuals face different costs for different sites in the case of multi-site models. The responses of the individuals to the variation in the travel cost of visits to different recreation sites are the basis for estimating the demand for recreation access to the site(s) (Freeman, Herriges, Kling, 2014). Following the

model defined by Zawacki, Marsinko, and Bowker (2000), the general specification of demand for downhill skiing trips can be expressed as:

$$Y_{ik} = f(C_{ik}, S_{ik}, R_k, D_i) \quad (2.1)$$

Where Y_{ik} is the number of trips taken by the i^{th} individual or group to site k , C_{ik} is the cost of i^{th} individual's trip to site k including time cost, S_{ik} is a substitute variable related to site k for individual or group i , R_k are the resource variables associated with site k , and D_i is a vector of socioeconomic variables for individual or group i .

Trip data collected on-site can lead to the well-documented problems of non-negative integer counts, truncation, and endogenous stratification (Creel & Loomis, 1990; Shaw, 1988). Estimators are biased if these problems are not addressed properly (Hausman, Hall, & Griliches, 1984). Most often, travel cost models employ either a truncated Poisson or a truncated negative binomial estimator to address these problems. The model is given by

$$\text{Let } y_i^* = X_i\beta + \mu_i \quad \text{for } i = 1, \dots, N \quad (2.2)$$

$$\text{Where, } y_i = y_i^* \text{ if } y_i^* > 0$$

Where, y_i^* is i th individual or group's desired quantity (i.e., trips) demand, X_i is a vector of independent variables, y_i is observable quantity (i.e., trips) demanded; μ_i is random error with 0 mean and σ^2 variance.

Of note, data on on-site visits are usually overdispersed (i.e., the conditional visit mean and variance are unequal). This is very common in recreation where annual trip numbers can range from 1 to over 100. The truncated Poisson model can give inconsistent and inefficient parameter estimates if the variance and mean are not equal (Cameron & Trivedi, 1986; Englin & Shonkwiler, 1995a; Greene, 2000). Since the dependent variable is truncated at zero, the standard Poisson and negative binomial model yield biased estimation (Englin & Shonkwiler, 1995b; Shaw, 1988; Yen & Adamowicz, 1993). The truncated Poisson and negative binomial model have been used in previous recreation demand research using on-site interviews (Cho, Bowker, English, Roberts, & Kim, 2014; Martínez-Espiñeira & Amoako-Tuffour, 2008; Shrestha, Seidl, & Moraes, 2002; Yen & Adamowicz, 1993). Due to this common criticism of mean-variance equality, researchers (Cameron & Trivedi, 1998; Englin & Shonkwiler, 1995a) introduce a parameter (α) which addresses the unexplained heteroscedasticity in the demand model. Englin and Shonkwiler (1995a) developed a truncated, endogenously stratified negative binomial model which can be applied to on-site survey data to estimate consumer welfare. Ovaskainen, Mikkola, and Pouta (2001) found that models adjusted for zero truncated and endogenously stratification perform slightly better than those only adjusted for zero truncation by comparing the results from stratified and non-stratified models. But, they found that adjustment for endogenous stratification had an insignificant effect on the estimated coefficients and CS. As several other studies (Dobbs, 1993; Loomis, 2003; Shrestha et al., 2002) also had similar conclusions, the model in this study only addresses the issue of over-dispersion and truncation in the data. Following Cameron and Trivedi (1998) and Englin and Shonkwiler (1995a), the

probability density function of the negative binomial distribution truncated at zero for count (y) can be represented as:

$$Prob(Y = y|Y > 0) = \left[\frac{\left(\tau \frac{y+1}{\alpha}\right)}{\tau(y+1)\tau\left(\frac{1}{\alpha}\right)} \right] (\alpha\lambda)^y ((1 + \alpha\lambda)^{-(y+\frac{1}{\alpha})} [1 - F_{NB(0)}]^{-1}, \quad (2.3)$$

where λ is parameterized as $e^{X'\beta}$.

2.5.2 Visitor survey data

Trip profile data were obtained from the NVUM program. The NVUM survey is the on-site survey program conducted to estimate the volume of recreation use on national forests. Authorized interviewers administer the survey to obtain information on 200 variables from 7,532 sites across the country using stratified random sampling methods. They collect the data from 20% of 155 national forests every year in a five-year cycle (English, Kocis, Zarnoch, & Arnold, 2002). The program provides science-based estimation of the volume and characteristics of recreation visitation which helps the FS effectively manage its resources (USDA Forest Service, 2007). Here, respondents were randomly chosen when they exited ski sites, and when there was more than one person in a car or group, the respondent with the most recent birthday was selected to avoid interviewer selection bias. Interviews were administered only to visitors who recreated at the site and were leaving for the last time that day (English et al., 2002).

The data for analysis were collected from 2005 to 2014, totaling 16,095 recreation visit observations, making it one of the larger data sets among TCM studies. The survey collected a

wide range of information on ski visits including socio-economic information, purpose of the visit, primary and secondary activities, annual number of visits, time spent at the ski site, arrival and departure time, satisfaction level of visits, number of people in the party, number of people under 16 years old, trip expenditures, and annual household income. The annual number of visits for downhill skiing (downhill skiing or snowboarding) was the dependent variable in the demand model. This was obtained via a series of NVUM questions. First, the respondent was asked about activities in which they participated on this trip. Next, they were asked to identify their “primary activity” for this visit. After responding to a question asking about total trips in the previous 12 months for all activities, respondents were then asked, “How many of those visits were to participate in the main activity you identified a moment ago?” All respondents received the participation questions from the NVUM survey.

Some adjustments were performed on the dataset due to theoretical and empirical reasons. Multipurpose and multi-destination trips are more complicated because trip expenses can no longer be attributed to just one recreation activity or site. Since there is not a systematic method to parse out travel cost for individual activities (Parsons, 2003), the accepted protocol was followed and only included observations with downhill skiing as the primary purpose of the visit. Visits from foreign countries, and outside the conterminous United States (Alaska, Hawaii, Puerto Rico, Virgin Islands) were not included because the nature of these visits differs from the conterminous United States. The long distance travelers are not well described by the recreational demand model as they are likely to use air travel which often has low correlation between cost and distance travelled. Therefore, we trimmed observations if one-way distance

traveled was greater than 1,000 miles, a procedure used in numerous other studies (Bin, Landry, Ellis, & Vogelsong, 2005; Bowker, English, & Donovan, 1996; Hellersetin, 1991).

Another challenge in travel cost modelling is to define the substitute site. The economics module of the NVUM questionnaire, distributed to about 1/3 of the sample, included a question about substitutes (for this visit), but it was distributed to just one-third of the respondents. Economic theory suggests that substitute prices/goods or their proxies should be included in demand models (Parsons, 2017, p. 191) and valuation of a site may be subject to bias if substitute sites or prices are not included in the analysis (Rosenthal, 1987). Various approaches have been used for substitute sites in travel cost modelling: including the price of substitute (Cho et al., 2014; Sardana et al., 2016); a dummy variable indicating whether or not a respondent intend to visit a substitute site (Bowker & Leeworthy, 1998; Martínez-Espiñeira & Amoako-Tuffour, 2008); using number of trips to substitute sites as a substitute variable (Loomis & McTernan, 2014); and using a substitute index based on recreation opportunities available (Bergstrom & Cordell, 1991). Because finding a substitute site is challenging in multi-site studies, we used a heuristic rule to assume the nearest downhill skiing site to visitors' origin and constructed a substitute distance variable that provided one-way distance from visitor's origin to the next nearest ski site not visited for that particular trip. Such an approach is an obvious compromise when someone is traveling to a skiing destination specifically because it offers an experience different than their local ski area, (e.g., an iconic destination). Ski sites located inside as well as outside the national forests boundary were considered as substitutes. Based on the data, 357 ski sites in national forests were visited from 2005 to 2014, and there were 383 additional ski sites

available outside the national forests making 740 substitute ski sites nationally. An estimated model using only substitute sites from within national forests did not significantly affect either the sign or magnitude of the substitute coefficient or the travel cost coefficient.

The reported annual number of ski visits was as high as 731 in the data. As the “last exiting” sampling procedure precludes more than one visit per day, and because skiing in the United States is not a year round activity, the trips were censored according to ski season length. Following National Ski Areas Association’s reports on average ski areas open days from 2004 to 2008 (NSAA, 2008) and from 2012 to 2014 (NSAA, 2014), typical length of ski season was found to be as high as 159 days. Therefore, anything higher was censored. Such censoring is typical (Bowker et al., 2009; Egan & Herriges, 2006; Englin & Shonkwiler, 1995a; Sardana, Bergstrom, & Bowker, 2016). Observations where the number of people traveling in the vehicle was reported more than 10 were also deleted because large-group travel could be a non-recreational trip and skiers in a large group are likely to have different ski demand. Location of ski site is important in this study for calculating travel distance and combining site-specific climate data but 2,420 observations did not have latitude/longitude information, and the missing values were replaced by ZIP code of the closest ski sites within the national forest. If the national forest had more than one ski site, the ZIP code of the most visited ski site in that national forest was used to replace the missing location information.

NVUM data contained household income and trip expenditures for only 4,339 observations because protocol requires that the economics module with questions related to income, expenditures, and substitutes only be administered to about one-third of those surveyed

(USDA Forest Service, 2007). To use as many observations as possible, but minimize the potential bias due to missing income, Mingie, Poudyal, Bowker, Mengak, and Siry (2017) and Kim, Shaw, and Woodward (2007) were followed, and estimated annual household income¹ as a proxy from data in the basic survey (administered to all respondents) by regressing household income on respondent's gender, age, number of people under 16 in the party, and adjusted gross income from the Internal Revenue Service for the respondent's ZIP code (Regression results: $\text{household income} = -53441.5 + 1080.8(\text{gender binary, male}=1) + 0.14(\text{IRS's gross income}) + 4987.1(\text{age}) - 45.2(\text{age square}) + 6890.6(\text{number of people under 16 in the travelling group})$, $R^2 = 0.27$). Parameter estimates from this regression model (n=4,339) were used to estimate household income. The estimated household income was used in the demand function. NVUM data do not have information on mode of transportation and type of vehicle used during travel. CDXZipStream, an Excel add-in to import and analyze ZIP code data in Microsoft Excel, was used to calculate the driving distances and times via the CDXRouteBing function between origin and destination ZIP codes. After trimming the observations (travelling distance more than 1,000 miles, large traveling group, ski visits during offseason, total annual visits more than season length), and dropping observations with missing values of important variables, a total of 8,974

¹ The models with original income variable, which is available to one-third of the data, were estimated and the sign and magnitude of coefficient of income and other variables were consistent with the models using estimated income. For brevity and minimizing the bias due to missing income, only the models with estimated income is presented in this paper.

observations were analyzed. The mean values of important variables in original and trimmed datasets were not different statistically.

For climatic variables, historical monthly climate data from the National Oceanic and Atmospheric Administration's (NOAA) Global Historical Climatology Network (GHCN) were used. The GHCN database contains daily historical temperature, rainfall, snowfall, and maximum snow depth for more than 100,000 stations worldwide. Monthly data were derived from the Global Historical Climate Network (GHCN)-daily database. Monthly mean climatic data were used to construct annual and seasonal means along with means of shoulder months. As the time span of the data includes the recent recession and its aftermath, dummies were included for interviews occurring from December 2007 through December 2010. Table 2.1 provides the definition and description of the variables used in the model.

Table 2. 1 Definition, and descriptive statistics of variables used in travel cost model of demand for developed skiing trips to U.S. national forests (N=8,974)

Variable	Definition	Mean	Std. Dev.	Min	Max
TRIPS	Annual trips to national forests for the primary purpose of skiing	16.1	21.1	1	150
TCOST1	Travel cost with no opportunity cost of time assumed	114.7	93	0.35	637.6
TCOST2	Travel cost with opportunity cost based on 33% of wage	188.6	201.9	0.93	2697.3
ROCKY	Dummy variables, 1 if Rocky Mountain region, 0 otherwise	0.6	0.4	0	1
SUBDIST	One-way travel distance from origin to closest substitute site in miles	47.8	56.4	0.28	563.6
INCOME	Estimated mean annual income	81072.7	22706.5	21582.4	242591
AGE	Age of the respondents	41.2	14.4	16	70
AGESQR	AGE * AGE	1906.88	1251.1	256	4900
MALE	Dummy variable, 1 if the respondent was male, 0 otherwise	0.69	0.46	0	1
PEOPVEH	Total number of people in the vehicle during ski trip	2.59	1.4	1	10
UNDER16	Number of people under 16 during ski trip	0.56	1.01	0	6
TIME	Hours spent on the ski site during the trip	5.09	4.2	1	98
RECESSION	Dummy variable, 1 if the year of interview was between recession and aftermath period (Dec 2007-Dec 2010), 0 otherwise	0.3	0.46	0	1
ROUND3	Dummy variable, 1 if the respondent was surveyed in Round 3 (2010-2014), 0 otherwise	0.39	0.49	0	1

Table 2. 1 Contd.

Variable	Definition	Mean	Std. Dev.	Min	Max
ELEVATION	Elevation in meters	2063.2	756.8	105	3575
Climate variables					
STEMP	Seasonal monthly mean temperature (in Celsius) at the ski site in the study season	-0.37	3.5	-12.8	15.7
SSNOWDEPTH	Seasonal maximum snow depth (in centimeters) within a month at the ski site in the study season	33.2	34.2	0	163.4
SSNOWDEPTHSQ R	Square of SSNOWDEPTH	2278.1	4291.5	0	26701
SRAIN	Seasonal average monthly rainfall (in millimeters) at the ski site in the study season	69.8	66.3	0	348.5

2.5.3 Empirical model

Using the general demand function described in the equation (2.1), the empirical model of demand for downhill skiing trips to national forests was specified as follows:

$$TRIPS_{ik} = f \left(\begin{matrix} TC_{ik}, ROCKY_k, SUB_{ik}, SE_i, PEOPVEH_{ik}, \\ UNDER16_{ik}, TIME_{ik}, RECESSION, ROUND, CL_k, EL_k \end{matrix} \right) + \mu_{ik} \quad (2.4)$$

Where, $TRIPS_{ik}$ represents the number of annual trips taken by individual or group i to site k , TC_{ik} is the associate travel cost, $ROCKY_k$ is a binary variable denoting observations from sites in the Rocky Mountain region, SUB_{ik} is the distance between the origin and the next nearest ski site, SE_i represents social-economic variables of individual or group including estimated annual income, age, and gender, $PEOPVEH_{ik}$ is number of people in the travel party, $UNDER16_{ik}$ is the number of people under sixteen in the travel party, $TIME_{ik}$ is the time spent at the site in hours, $RECESSION$ is a binary variable if the visit was during the recession or its aftermath, $ROUND3$ is the dummy variable if the visit was during Round 3 of NVUM survey, CL_k are climatic variables at site k , EL_k is the approximate elevation of site. The term u_{ik} is random error.

Following Sardana et al. (2016), the annual number of downhill skiing trips by an individual or group was used as the dependent variable for analysis as the sampling unit for NVUM survey was a single person or a group of people travelling together. While previous research used overnight stay in ski resorts (Falk, 2010; Pickering, Castley, & Burt, 2010; Surugiu, Dincă, & Micu, 2010; Surugiu, Surugiu, Frent, & Brenda, 2011; Töglhofer et al., 2011)

and lift ticket sales or visitation rate (Demiroglu, Kučerová, & Ozcelebi, 2015; Gonseth, 2013; Hamilton et al., 2007; Pickering, 2011; Shih et al., 2009), number of trip was used to measure participation and use of the ski areas.

Following Parsons (2017, p. 215), the mileage rate was set at the variable operating costs including gas, maintenance, and tires. Fixed costs such as insurance (Knoche & Lupi, 2013) and depreciation were not included in the mileage rate. Knoche and Lupi (2013) and Smith and Moore (2013) included depreciation in their mileage rate, but this is generally avoided because it is considered part of the fixed cost of ownership (Parsons, 2017). The average variable operating cost of a medium sedan was \$0.177 (American Automobile Association [AAA], 2017). There is no consensus about treatment of travel time in the literature (Martínez-Espiñeira & Amoako-Tuffour, 2008; Randall, 1994; Zawacki et al., 2000) and its role in recreation demand remains unresolved (Phaneuf & Smith, 2005). The most common practice is to value travel time at the wage rate or some fraction of it (Phaneuf & Smith, 2005; Englin & Moeltner, 2004). Two travel cost variables were constructed based on two different assumptions of wage rate: a conservative case with no wage rate (*TCOST1*) and alternative using 1/3 of the household wage rate (*TCOST2*). *TCOST1* was the product of round trip driving distance and mileage rate plus respondent-reported recreation fees (i.e., entry, parking, recreation fee) that were necessary to access the site. *TCOST2* added the product of travel time and 1/3 the wage rate to *TCOST1*. Following Loomis & McTernan (2014), the wage rate was calculated by dividing annual household income by total number of hours (2080) in a year. It is noted that reported recreation fees were added, but NVUM data contained no information on season passes or other types of

discounts. Season passes were treated as a long term demand issue following Englin and Moeltner (2004). Parsons (2017, p.215) stated that typically only a daily fee is used in the travel cost variable, and accounting for annual, season, or weekly passes is difficult and generally ignored, or possible incorporated into the participation portion of a two-stage model. A large dataset like NVUM's does not simply contain the type of details available at single-site or multiple-sites in a given market. In the case of skiing, ticket pricing varies throughout the season although many skiers purchase season passes (NSAA, 2017). The lift or ski ticket prices may vary by weekend or weekday, half-day or full day or two-day ticket, and age of the skiers. Other factors such as complimentary ticket rates, promotional rates, pre-purchase deals, online ticket brokers, resort-operated loyalty, and package deals also make it difficult to accurately determine individuals' lift ticket price (NSAA, 2017).

To control for the regional differences in ski demand, a binary variable was added to denote the Rocky Mountain region. This region covered eight states (Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming) of Resources Planning Act (RPA)'s Rocky Mountain region. The NSAA's Rocky Mountain region also includes the same seven states except Nevada. The result of the Rocky Mountain region was compared with two other regions because more than half of the observations were from the Rocky Mountain region and the region has many popular ski areas in the national forests. In addition, skiers in the Rocky Mountain region, on average, had the highest annual visits per person (18) and they travelled the longest one-way distance (136 miles) compared to other regions. The climatic variables such as snowfall and rainfall, which are expected to affect the skiing conditions, are also different in the

Rocky Mountain region in comparison to other regions. For instance, mean snowfall was 29 cm in the Rocky Mountain region compared to 37 and 44 cm in the North and Pacific regions, respectively. Similarly, rainfall was 40 mm in the Rocky Mountain region compared to 108 and 116 mm in the North and Pacific region, respectively.

Many aspects of travel cost modeling have been debated including on-site time (Amoako-Tuffour & Martinez-Espineira, 2012; Landry & McConnel, 2007; McConnel, 1992) which is a source of utility as well as cost in the demand function (Acharya, Hatch, & Clonts, 2003). Freeman et al. (2014, p. 300) mentioned that on-site time should theoretically be included in the demand function, and on-site time becomes constant only if all visitors choose visits of the exact same duration and if they all have same opportunity cost of time (McConnell, 1992). Similarly, Acharya et al. (2003) found that exclusion of on-site time from demand function would result in biased estimation (i.e. smaller price effect, and larger CS). For this reason, the previous studies (e.g., Acharya et al. 2003; Amoako-Tuffour & Martinez-Espineira, 2012; Bowker et al., 1996; Bell & Leeworthy, 1990; Creel & Loomis, 1990; Martinez-Espineira & Amoako-Tuffour, 2008; Melstrom, 2013; Shresthat et al., 2002) were followed, and included on-site time in the demand model. The estimated travel cost parameter from the demand function is used to calculate the net economic value or net benefit associated with accessing ski areas, also known as consumer surplus (CS). The CS per trip can be derived from the truncated count data estimator as the negative inverse of the estimated travel cost coefficient. Therefore, estimated coefficients from the equation (2.4) were used to calculate average per trip CS per group and CS per person per trip was calculated by dividing the value by average number of people per group.

$$CS = -\left(\frac{1}{\beta_{TC}}\right) \quad (2.5)$$

As a part of the 2010 USDA Forest Service RPA Assessment, Joyce et al. (2014) presented future climate projections based on various scenarios of projected change in population, economic growth, and land use change. Specifically, they used three scenarios (A1B, A2, and B2) from the IPCC Special Report on Emission to project county level temperature and precipitation for the coterminous United States. The A1B scenario, which is based on three climate models (the Third Generation Coupled Global Climate Model (CGCM3.1), the Climate System Model (CSIRO-MK3.5), and the Model for Interdisciplinary Research on Climate (MIROC3.2)), has intermediate greenhouse gas emission values and a balanced future use of fossil fuels and non-fossil energy sources compared to other two scenarios. Researchers have chosen the A1B scenario to analyze relative concentration of climate change (Poudyal, Elkins, Nibbelink, Cordell, & Gyawali, 2016) and to predict recreation participation on federal lands in the future (White et al. 2016). Therefore, the projected seasonal mean temperature were chosen and seasonal mean precipitation data for A1B scenario from Joyce et al. (2014) for the counties where skier information was collected. The projected mean temperature and precipitation for the year 2060 was found to be +2.72°C and +4.25 mm, respectively. Since they did not project snow depth for 2060; snowfall by location for 2060 was imputed by regressing past snowfall on temperature, precipitation, elevation, and then, snow depth for 2060 was imputed using regression of snow depth on temperature, precipitation, snowfall, and elevation (Regression results: seasonal snow fall = -6.31 -1.5 (seasonal temperature) + 0.15 (seasonal rainfall) + 0.005 (elevation), R²=0.54; seasonal snow depth = -1.52 - 0.8 (seasonal temperature) -0.004 (seasonal

rainfall) + 2.3 (seasonal snow fall) + 0.0009 (elevation), $R^2 = 0.83$). The projected changes in climatic factors were only considered and all the other variables in the model were assumed to be constant for 2060.

The conditional mean of ski visits with a truncated negative binomial regression was predicted following Cameron and Trivedi (2012, p. 131). As defined by Cho et al. (2014) and Heberling and Templeton (2009), the difference in expected number of trips in 2016 and 2060 was estimated and calculated the difference in trips due to projected climate variable changes in 2060 assuming other factors affecting the demand for skiing remained the same. The percentage change in CS due to climate change can be defined as:

$$\Delta CS = \left(\frac{E(y_i|x_i) - E(y_i|x_i)_{CC}}{E(y_i|x_i)} \right) * \frac{-\left(\frac{1}{\beta_{TC}}\right)}{PEOPVEH_i} * NAV \quad (2.6)$$

Where $E(y_i|y_i)$ is the individual average expected number of visits in the base year, $E(y_i|x_i)_{CC}$ is the individual average expected number of visits under climate change forecast for 2060, β_{TC} is the coefficient of travel cost variable, $PEOPVEH_i$ is average number of people in the vehicle. The NAV is the average number visits to ski sites in the national forests over Rounds 2 and 3.

The definitions and descriptive statistics of the variables used in the model are reported in Table 2.1. The number of trips, represented by $TRIPS$, taken by skiers or snowboarders within a year was modeled as the dependent variable of the demand model. The explanatory variables include two travel cost alternatives ($TCOST1$ and $TCOST2$) as described above, a binary variable

representing whether the respondent was sampled at a ski site in the Rocky Mountain region (*ROCKY*), a substitute location variable representing the distance between respondent's home and the nearest ski site not visited (*SUBDIST*), estimated household income (*INCOME*), and age of the respondent (*AGE*). A quadratic for age (*AGESQR*) was used to capture any potential curvilinear relationship between visits and age as is often the case with recreation models for outdoor recreation and participation (Bowker et al., 2012). Other variables included a binary variable for gender (*GENDER*, *male*=1), number of people in the travelling group or vehicle (*PEOPVEH*), number of people under 16 in the trip (*UNDER16*), the time spent at the ski site in hours (*TIME*), if the interview was taken during recession or its aftermath (*RECESSION*), a binary variable representing whether the interviews were taken during Round 3 (2010-2014) of NVUM survey (*ROUND3*), and elevation of the ski area in meters (*ELEVATION*). As mentioned in the equation (2.4), an elevation variable was added to the model because snow depth and temperature are predictors of skiing demand only at lower altitudes (Falk, 2010; Töglhofer et al., 2011).

The models were analyzed using the climatic average along with socio-economic information of the respondents as defined in the equation (2.4). Those climatic variables were, *STEMP*, seasonal monthly mean temperature in degree Celsius (°C) at the ski site, (*SSNOWDEPTH*), seasonal maximum snow depth in centimeters within a month at the ski site. Because Englin and Moeltner (2004) found a non-linear relation between ski demand and snowfall, a quadratic of snow depth (*SSNOWDEPTHSSQR*) was added, to see if their result holds

for national level estimation. Similarly, *SRAIN* was seasonal average monthly rainfall at the ski site in millimeters.

With 8,974 observations available for analysis, the average annual number of trips to ski sites was just over 16 (Table 2.1). The average cost of two-way travel between respondent's home to ski site ranged from \$115 to \$189 based on the assumption of wage rate. More than half (60%) of respondents went to the national forest ski sites in the Rocky Mountain region. The one-way distance from origin to ski site, on average, was 129 miles and one-way distance to the closest ski site from the respondent's home was 48 miles. On average, respondents were 41 years old with household income of \$81,072; almost 70% were male. The average number of people in a travel group was 2.59, and number of people under 16 years old was 0.6. The mean number of hours respondents spent for downhill skiing was 5.1 whereas average elevation of the ski areas was 2,063 meters. On average, seasonal monthly mean temperature was -0.4°C , seasonal maximum snow depth was 33 cm, and seasonal average monthly rainfall across ski sites was 70 mm.

2.6 Results and discussion

2.6.1 Regression estimates

Demand model estimates are presented in Table 2.2. Truncated Poisson and truncated negative binomial models were estimated, but results from Poisson are not reported because the equality of the mean and variance was rejected. The models with annual and seasonal climatic means were estimated, but the sign and magnitude of the coefficient was essentially the same in

Table 2. 2 Regression estimates from alternative models of developed skiing demand at U.S. National Forests, by alternative assumption of wage rate (N=8,974)

Travel Cost and Socio-Economic variables	No wage rate	33% wage rate
TCOST	-0.0043(0.0002**)	-0.00209(0.0001**)
ROCKY	0.254(0.05**)	0.257(0.06**)
SUBDIST	-0.004(0.0004**)	-0.003(0.0004**)
INCOME	0.00001(0.000002**)	0.00003(0.000004**)
AGE	-0.087(0.01**)	-0.196(0.02**)
AGESQR	0.001(0.0001**)	0.002(0.0002**)
MALE	0.173(0.04**)	0.124(0.04**)
PEOPVEH	-0.237(0.02**)	-0.240(0.02**)
UNDER16	-0.089(0.03**)	-0.227(0.04**)
TIME	-0.017(0.004**)	-0.017(0.004**)
RECESSION	-0.027(0.04)	-0.030(0.036)
ROUND3	0.069(0.04)	0.05(0.04)
ELEVATION	-0.0002(0.00003**)	-0.0002(0.00004**)
Climatic variables		
STEMP	-0.029(0.01**)	-0.029(0.006**)
SSNOWDEPTH	0.01(0.002**)	0.006(0.002**)
SSNOWDEPTHSQ	-0.00005(0.00001**)	-0.00002(0.00001*)
SRAIN	-0.002(0.0004**)	-0.002(0.0004**)
INTERCEPT	4.538 (0.21**)	5.512(0.25**)
LOG-LIKELIHOOD VALUE	-31338.64	-31314.85
AIC STATISTICS	62715.29	62667.7

Note: ** and * indicates statistical significance at $\alpha = 0.01$ and $\alpha = 0.05$ level, and numbers in parentheses are standard errors.

both models. For brevity, only seasonal models are presented in the paper. They also slightly outperformed annual models based on Akaike Information Criterion (AIC). It was assumed that climatic effects were better captured with seasonal measures than annual measures because skiing is a seasonal activity. The signs and significance of the coefficients on most variables were consistent with economic theory except for substitute distance. All coefficients were significant at the 0.05 level except *RECESSION* and *ROUND3* in both models, and *SSNOWDEPTHSQR* in the model with a 33% wage rate assumption.

The coefficients on the travel cost variables (*TCOST*) were significant and negative for both wage rate assumptions suggesting that downhill skiing conforms to economic theory. This is consistent with results from previous skiing studies (Bergstrom & Cordell, 1991; Englin & Moentlier, 2004). The *ROCKY* dummy was positive and significant in both models suggesting higher demand for downhill skiing in the Rocky Mountain region than other regions. This observation is consistent with the region having numerous popular and iconic ski resorts (NSAA, 2008). The Rocky Mountain region also accounts for more than one-third of all U.S. skier visits, the largest number in the country (Burakowski & Magnusson, 2012; Dawson, 2009). Since *ROCKY* was statistically significant as an intercept shifter in the ski demand function, the price interaction effects indicating a different price response than other regions were tested and found the effects insignificant in both models.

The negative sign for substitute distance (*SUBDIST*) appears counter-intuitive indicating as the distance (price) to alternative skiing sites increases, skiers will take fewer trips to the national forest site where sampled. Many travel cost studies also found negative substitution

effects (Bowker et al., 2009; Cho et al., 2014; Loomis & McTernan, 2014). The relationship between demand and substitute price is expected to be positive in the case of perfect substitutes, but defining substitutes is difficult in recreation demand because the choice of the substitute sites may vary across individuals, time of the year, types of activities, site quality attributes, and price of participation at the substitute sites (Bowker et al., 2009). Substitute choice information available in one-third of the NVUM data (economics module), revealed that only about 40% of respondents would go to a substitute site for skiing if their current visit site were unavailable. Other substitute choices in the NVUM survey included staying at home (20.3%), coming back another time for skiing (18%), going somewhere else for another activity (12.6%), going to work (5.4%), and other reasons (3.4%). Although these data are only available for one-third of the sample, they suggest that simple substitution variables, commonly used in travel cost modeling may be problematic given the complex nature of recreation behavior. As Freeman (1992, p. 454) points out, there is no simple answer to the question of how to select substitute sites.

The coefficient on household income (*INCOME*) was positive and significant, suggesting that demand for downhill skiing increases with higher income. This is consistent with previous studies on skiing demand (Bergstrom & Cordell, 1991; Englin & Moeltner, 2004), and many other studies on outdoor recreation showing a positive income effect (Martínez-Espíñeira & Amoako-Tuffour, 2008; Zawacki et al., 2000). The negative and significant coefficient of number of people traveling in the vehicle (*PEOPVEH*) suggests that the demand for skiing trips decreases with travel group size, which is in line with the results reported earlier (Cho et al.,

2014; Sardana et al., 2016). The result seems intuitive because trip planning depends on joint decisions by multiple members, who are constrained by many different factors.

As indicated by the negative and positive signs of coefficient of age (*AGE*) and quadratic of age (*AGESQR*), respectively, age seems to have a curvilinear relation with skiing demand. That U-shaped relationship implies the demand for skiing decreases with age up to a point and then begins to increase. Specifically, for the no-wage model, holding other factors constant, predicted ski trips decline from age 20 up to an inflection point in the mid-40's increasing thereafter through the relevant range of the data. NSAA (2015) reported that ski resorts were attracting younger skiers to replace older individuals. There was a 10% decrease in skiers in 2015 from a high of 31% of skiers aged 51-69 in year 2005-06, with the strongest growth attributed to skiers under 17. The estimated coefficient for the *GENDER* binary variable (male=1) was positive and significant in both models indicating that being male is correlated with more annual skiing trips. This observation is in line with the skiing study by Englin and Moeltner (2004), and for many types of outdoor recreation demand in general (Bowker et al., 1996; Sardana et al., 2016).

The coefficient associated with number of people under sixteen years of age (*UNDER16*) was negative and significant across the models, suggesting that ski trip demand decreases with the presence of children. The negative and significant sign on time spent on site (*TIME*) indicates that demand for ski trips decreases with increased hours on site spent engaged in skiing. The results are in line with findings of other recreation demand studies (Bell & Leeworthy, 1990; Creel & Loomis, 1990; Melstrom, 2013; Shrestha et al., 2002) which suggests that longer trip

duration for recreation activities is correlated with fewer trips. However, Acharya et al. (2003), Bowker et al. (1996), and Martinez-Espineira and Amoako-Tuffour (2008) found that recreationists who spend more time on site tend to visit the site more often. The coefficient on the recession binary variable (*RECESSION*) was found to be negative and statistically insignificant in both models, suggesting that the skiers participating in recession years did not report a significantly different number of trips than those participating in non-recession years. Poudyal, Paudel, and Tarrant (2013) found a negative effect of recession on demand for national park visits in the United States, but there is no literature precedent on skiing demand. Where skiing is highly related to income and recessions typically impact lower income people first, the recession effect is not realized. Alternatively, the process could be two-staged (i.e., a participation decision (ski or not) followed by a participation intensity decision (how often)). Thus, during a recession, individuals who are not directly impacted with job loss or salary reductions remain in the on-site sample and behave similarly to a non-recessionary period, while those adversely effected drop out of the sample and thus have no effect on the average number of participant trips. Without an origin-based sample, this is difficult to address. Similarly, the coefficient for Round 3 interviews (*ROUND3*) was found positive but statistically insignificant in both models, suggesting that skiing visits in Round 3 were not significantly different than Round 2.

Elevation (*ELEVATION*) is a key variable because climatic factors may vary with elevation. The negative coefficient of elevation suggests that skiers on sites of higher elevation are likely to take fewer trips than those visiting lower elevation sites. This result is

counterintuitive in that ski areas at higher elevations typically have more snow, lower temperature, and a longer ski season (Scott & McBoyle, 2007). However, sites located at lower elevations are perhaps more economically appealing, easier to access, and more appropriate for inexperienced skiers. Beginners or less skilled skiers are likely to prefer ski areas at lower elevation where terrain conditions and ski runs are suited to them, and skiers with family are perhaps more likely to ski in those areas. In addition, lower elevations are preferred by individuals with no previous experience at high altitude.

The climate factors in the models were significant and had the expected signs across both wage rate assumptions except for *SSNOWDEPTHSQR* in the model with a 33% wage rate assumption. The coefficients on temperature (*STEMP*) were found negative and significant suggesting that the demand for skiing trips was less in years and seasons with higher mean temperatures. The skiing literature shows a negative relation between the demand for skiing and temperature (Demiroglu et al., 2015; Englin & Moeltner, 2004; Hamilton et al., 2007; Loomis & Crespi, 1999; Shih et al., 2009; Surugiu et al., 2010). Higher temperatures could increase snow melting and also decrease the opportunities for natural snowfall. Moreover, the efficiency of artificial snowmaking capacity declines as temperature increases. However, Falk (2013) and Töglhofer et al. (2011) mentioned that the effect of temperature on winter tourism demand is complex. For example, Falk (2013) found that average temperature is positively related ski demand in the long run, but negatively related in the short term.

The positive sign on snow depth (*SSNOWDEPTH*) combined with the negative sign on its square (*SSNOWDEPTHSQR*) indicates that the skiing demand increases with snow depth but

at a decreasing rate. The negative coefficient for temperature and positive coefficient of snow depth shows skiers prefer colder temperatures with more snow depth. Englin and Moeltner (2004) found a similar quadratic relationship for snowfall. As expected, many other studies also reported a positive relationship between skiing demand and snow depth (Demiroglu et al., 2015; Englin & Moeltner, 2004; Falk, 2010, 2013, 2015; Fukushima, Kureha, Ozaki, Fujimori, & Harasawa, 2002; Hamilton et al., 2007; Shih et al., 2009; Töglhofer et al., 2011). The negative and significant coefficient on rainfall (*RAIN*) suggests that the demand for skiing trips in year and seasons with higher rainfall around ski sites was less than that in drier years and seasons. Rainfall naturally degrades ski conditions, and it also makes driving condition difficult in winter.

2.6.2 Economic welfare estimates

The economic value of downhill skiing trips was derived by combining the estimated travel cost coefficients in Table 2.2 with the equation presented in the equation (2.5). The CS per trip was divided by mean number of people in the traveling groups ($PEOPVEH = 2.59$) to obtain CS per person per trip. Table 2.3 presents the CS estimates along with 95% confidence intervals. Following Kling and Sexton (1990) and Martinez-Espineira and Amoako-Tuffour (2008), the confidence intervals for CS were calculated through bootstrapping the standard errors. With no opportunity cost of time assumed, the estimated per person per trip CS was \$91(\$82, \$102). When an opportunity cost of 33% of the wage rate was assumed CS increased to \$185 (\$145, \$253). The CS per trip from this study is in line with estimates reported in previous studies. Englin and Moeltner (2004) assessed the skiing trips by 131 college students at 13 ski resorts and found per person per trip CS value of \$98 (\$63, \$136). They incorporated physical

Table 2. 3 Consumer surplus per trip per person for developed skiing at U.S. National Forests, by alternative assumption of wage rate (2016 dollar)

No wage rate	33% wage rate
\$91 (\$82, \$102)	\$185 (\$145, \$253)

Note: 95% confidence intervals are in parentheses.

characteristics of the ski site as well as climatic variables in the demand model, and entry fee was also included in the travel cost variable. They found per person per trip snowboarding CS of \$47 (\$42, \$53). Snowboarders had a higher demand intercept, but were more responsive to cost than skiers. The NVUM survey did not separate the observations for downhill skiers and snowboarders; therefore, the estimation for individual activity could not be calculated separately.

Despite some limitations of the data used for the analysis, Bowker et al. (2009) estimated the economics value of 14 recreation activities, including downhill skiing and found per person per trip CS of \$162 (no wage rate) and \$234 (33% wage rate), respectively. They did not consider climate variables in the demand function. Bergstrom and Cordell (1991) found per person per trip CS of \$62 using county level data and a zonal travel cost model framework combined with a reverse gravity model. While two of the earlier studies, Cicchetti et al. (1976) and Walsh and Davitt (1983) found per person per trip CS of \$27 and \$59, respectively, methods available at the time of their analysis did not account for truncation or the count nature of the data. A list of previous studies on downhill skiing along with their CS estimation, study area, CS estimation method, and source of data are included in Appendix A.

2.6.3 National economic benefits estimation

Per person per trip CS from Table 2.3 and NVUM annual visits estimation of downhill skiing (USDA Forest Service, 2017) were used to derive the total annual economic benefits at the national level. Based on the NVUM estimation from 2005 to 2014, average annual recreational visit to national forests was approximately 151.21million, of which 23.71 million

visits were primarily for downhill skiing. Nationwide the net benefit of downhill skiing on national forest lands was \$2.16 billion (no wage rate assumed) and \$4.39 billion (33% of wage rate assumed). The U.S. Forest Service (2012) reported spending by skiers to national forests contributes about \$4.27 billion to the national economy annually. Although the contribution of skiers to local economies and the national economy is not comparable to the results of this study, the estimation of CS provides another means to compare the relative value of downhill skiing in national forests. Bergstrom and Cordell (1991) estimated the annual nationwide net economic benefit of skiing at \$4 billion and national forests' share would be \$1.6 billion by considering 40% of national ski visits is in the national forests (NSAA, 2016), which is less than economic value found in this study. Though their study analyzed national level data, they utilized a zonal TCM which is susceptible to aggregation bias (Moeltner, 2003) and considered less precise. Additionally, the PARVS data they used is not entirely representative of all the ski sites in the United States. More importantly, they suggested viewing their results with caution because of a small sample size for skiing.

The results demonstrate that downhill skiing on public lands, particularly national forests, is an important source of benefits, and these results may be more readily generalizable to the national skier population as almost half of annual ski visits in the country occur on national forests. While this study showed substantial economic value, the CS estimates totals could be conservative. First, only the observations with one-way driving distance of less than 1,000 miles were analyzed as data from long distance and international travelers was trimmed. Second, we

assessed value only accruing to those who listed downhill skiing as their primary purpose for travel. Thus, side trips while on business or visiting family were not included.

Alternatively, it could be argued that per-trip CS estimates are over-estimated because of measurement error problem in the construction of travel costs. Such error occurs when factors comprising the constructed travel cost, e.g., wage rate, mileage rate, lift tickets, and the like are not accurately measured; a problem endemic to nearly all travel cost applications in one form or another. Parresol et al. (2017) demonstrated regression attenuation bias resulting from covariate measurement error can negatively bias coefficient estimates. In count models, where the CS per trip estimate is the negative inverse of the travel cost coefficient (equation 2.5), the bias leads to inflated CS estimates, although the magnitude of the bias is difficult to discern. This problem is rarely if ever addressed in the travel cost literature.

2.6.4 Changes in welfare due to climate change

Table 2.4 shows the projected mean of ski visits in, percentage decrease in annual visits and welfare loss due to expected climate change, and projected CS in 2060, relative to 2016. The predicted mean annual visits for the individual in the base year were found to be 13.33 (no wage rate assumed) and 13.24 (33% of wage rate assumed). Compared to the predicted individual visits in the base year, the projected annual visits in 2060 would decrease by 7.95% (12.27 visits) and 8.53% (12.11 visits) in the models with no wage rate and 33% wage rate, respectively.

Since both temperature and precipitation are projected to increase while snow depth is projected to decrease by 2060, the economic value of downhill skiing in the nation is projected to

decrease. It was assumed that percentage decrease in annual visits on national forests would be at the same rate as the decrease in individual's visits. Following the equation (2.6), the changes in welfare in 2060 attributable to climate change was calculated. The projected decrease in annual aggregate CS was found to be \$171.57 million for the no-wage model, and \$374.36 million for the wage based model (Table 2.4). An alternative approach, acknowledging the potential danger of downward bias in the travel cost model coefficients, is to combine the trip predictions with alternative CS estimates in a simple benefit transfer approach. Averaging across studies reported in Appendix A, including snowboarding, yields a CS of \$59 per individual trip. This yields annual losses of \$111.24 million and \$119.39 million, respectively, for annual aggregate net economic value lost (Table 2.4).

Bowker et al. (2012) and White et al. (2016) projected increases in ski participation in the future in the absence of climate change mainly due to increases in population and income, but they found that the percentage increase in ski visits would decrease due to the effect of climate change. Using the National Survey on Recreation and the Environment (NSRE) telephone survey data, White et al. (2016) analyzed historical participation trends and projected a 35.1% increase in annual skiing visits to federal lands between 2008 and 2030. However, they projected increases in ski participation of 34.7% when climate change was taken into consideration. They found that increases in population and income were driving force to increase in ski participation. They used origin-based climate data and not site-based, and they did not include snow fall or snow depth, which are influential factors in determining skiing conditions.

Table 2. 4 Predicted change in annual visits and welfare impact under climate changes scenario through 2060 in U.S. National Forests

Model	Predicted visits in 2016	Predicted visits 2060	Decrease (%)	Loss in CS (millions dollars)	CS in 2060 (billion dollars)
No wage rate	13.33	12.27	7.95	171.57	1.99
33% wage rate	13.24	12.11	8.53	374.36	4.01

The projected change in climate variables could affect the quality of snow conditions in ski areas resulting in decreased skiing participation. The projection scenario included only changes in climate variables, and it did not account for reduced ski season length due to climate change. Wobus et al. (2017) projected decreased ski season length by 2050 in most places resulting in millions of foregone visits which could further decrease the CS from that reported here. The possible decline in the quality of ski sites on national forests due to climate change could present an important challenge to land managers and ski resort operators. A major challenge will be to ensure the ski opportunities and to maintain the quality of the ski areas which can be addressed through applying efficient and effective adaptation measures such as using advance snow making equipment. Recreation resource planners and ski site managers should put more emphasis on innovative management strategies to minimize the effect of climate change as much as financially possible. In addition, this result can be used to enhance public support for combating adverse effect of climate changes on the public lands.

2.7 Conclusion

The net economic benefit of skiing on the National Forest System was estimated, and the likely effect of climatic factors on skiing demand and the aggregate economic value of downhill skiing were assessed. First, the net economic benefit or consumer surplus skiers receive from accessing the national forests for a downhill skiing trip was estimated to be between \$91 and \$185. Nationwide, estimated aggregate net economic benefits ranged from \$2.16 to \$4.39 billion, implying that skiing on national forests generates substantial economic benefits for the public.

Second, findings suggest that the trip demand for and consumer surplus of downhill skiing shows significant responsiveness to climatic factors including temperature, snow depth, and rainfall. Temperature and rainfall negatively correlate with demand for skiing, whereas snow depth is positively related. The significance of these variables in the demand models indicates that failure to include climatic variables in the ski demand model may lead to omitted variable bias issues and yield biased welfare estimates. More importantly, including such variables allows ex ante analysis of future conditions if externally based models are available to predict climate futures. By assuming the socio-economic factors affecting the ski demand remain constant, the future projections under climate change show that for the current national forest skier population, participation as well as economic welfare will probably decrease. The magnitude of this decrease ranges from \$172 to \$374 million using the estimates of consumer surplus. A more conservative estimate of the loss in welfare, ranging from \$111 to \$119 million, is obtained coupling the visit projections with the average of consumer surplus estimates obtained from existing studies.

The projected decline in the average annual number of trips demanded by a population represented by current National Forest System skiers may inform recreation planners and land managers at respective national forests and regional managers to prepare to anticipate impacts due to activity substitution (increased participation in other winter sports) or site substitution (increased crowds at high elevation sites). Findings would also be helpful in the long term planning of ski areas in the national forests to optimize benefits in the context of climate change. More importantly, the results of this study can be used to inform the public and possibly enhance

public support for climate change adaptation and mitigation measures by the ski industry and relevant public land managers.

Third, estimates of the net economic benefit of access to national forest skiing venues presented in this analysis are derived from a rich dataset that covered multiple years and many ski sites across the nation. Estimates could be used by other public and private land management agencies to approximate the economic value of skiing on their sites through benefit transfer approaches. The uniqueness of this study lies in multiple aspects, including application of individual travel cost model to nationwide downhill skiing data from multiple years, more precise measurement of travel cost including recreation fees and various wage rates, and most importantly the inclusion of climatic variables, that affect the ski industry, but had never been examined before beyond the very local level. Findings have several implications in understanding the economic significance of skiing in National Forest System and comparing benefits and costs of managing ski resources on public lands.

Finally, there are some important limitations and caveats that should be acknowledged due to the nature of NVUM dataset and theoretical constraints underlying travel cost modeling. First, the NVUM survey does not collect the important site quality variables related to skiing such as lift sizes, terrain conditions, length of longest run, and size of run for different type of skiers, size of skiable area along with other facilities associated with ski areas. Future studies with more location specific objectives might consider using NVUM data coupled with more detailed information about the target sites. Similarly, snowmaking capacity of the ski area, one of the important ways to adapt and mitigate when availability of natural snow is limited, was not

included in the model. The availability of snow making capacity could affect the ski visitation in the future as the majority of ski areas already have it to maintain good ski conditions.

Another limitation relates to the NVUM data available to construct accurate travel costs. As pointed out by one reviewer, the fact that costs are approximated, especially costs associated with necessary fees like lift tickets, which are often bundled and discounted throughout the season, and an assumed wage rate is used, reported fees may contain considerable measurement error. Thus, the constructed travel cost variable will lead to a downward bias in the relevant parameter estimate. This bias, the magnitude of which is difficult to estimate, leads to an overestimate of consumer surplus in count data travel cost models. To offset this likely bias, relatively conservative mileage costs were used, eliminated very long distance visitors, and present alternative estimates of future welfare loss based on consumer surplus estimates available in the literature, although not pertaining to all national forests. An important avenue for research in future travel cost studies, especially ones where the travel costs are complex and data collection resources limited, would be to attempt to measure this bias and explore mitigation procedures as this measurement error bias problem is rarely discussed in travel cost studies.

Another limitation is the use of a generated income variable, primarily because NVUM data for income is only available for about a third of the sample. This problem can lead to both over and under estimation of coefficient and standard errors and thus affect hypothesis testing. Insofar as this generated variable allowed to increase the sample by more than 200 percent, and because any policy issues related to income elasticity were not specifically calculated or tested,

the trade-off was considered reasonable. Moreover, the travel cost coefficients were robust regardless of inclusion of income in demand model.

Lastly, the findings are for an overall picture of downhill skiing on the national forests and should be used cautiously when applied to specific ski areas, whether they are found inside or outside the National Forest System. Despite these limitations, this result is expected to be a baseline for the economic value of skiing in the United States and useful for future research.

CHAPTER 3

ASSESSING AND COMPARING THE DEMAND FOR AND VALUE OF NON-MOTORIZED BOATING ACCESS BETWEEN WILD AND SCENIC RIVER DESIGNATED AND NON-DESIGNATED RIVERS

Abstract

More than half of the 208 rivers currently designated by the U.S. Congress under the Wild and Scenic Rivers Act of 1968 are within the system of national forests and grasslands. Along with protecting rivers with outstanding values, the Wild and Scenic Rivers also provide recreation benefits to society. Previous studies have examined these designated rivers in many aspects, but none has assessed the effect of designation on the demand and economic value of recreational access to those rivers for popular activities such as non-motorized boating. In addition, there is a lack of reliable estimates of the economic value of non-motorized boating that could be generalized to a national scale. By combining trip data collected from on-site surveys in national forests across the nation with site and river characteristics data from secondary sources, this study developed an aggregated travel cost model to estimate the net economic benefits of non-motorized boating activities. The per person per trip net economic benefit of non-motorized boating was estimated to be in the range of \$66 to \$87 depending on the modeling assumption about boaters' opportunity cost of time. When aggregated across visits and national forests, the total economic value ranged from \$108.24 to \$142.68 million, annually. However, the designation did not signal a different demand for and economic value of non-motorized boating in designated than non-designated rivers. Further, site characteristics such as ramp availability, camp size, difficulty level were found to be significantly correlated with demand for non-motorized boating. Results may be useful in enhancing the recreational appeal of rivers for non-motorized boaters and in understanding the value of non-motorized boating on public lands in general and national forests in particular.

3.1 Introduction

The U. S. Congress passed the Wild and Scenic Rivers Act (WSRA) in 1968 to protect a river or a section of the rivers, or even tributaries with outstanding scenic, recreational, geologic, fish and wildlife, historic, cultural, or other similar river-related values nationally in a free-flowing condition for the benefits of present and future generations (Wild and Scenic Rivers Act, 1968). Beginning with 789 miles of 8 designated rivers, the Wild and Scenic Rivers (WSR) System currently protects 12,709 miles of 208 rivers in 40 states and Puerto Rico, which possess less than 0.25% of the total river system in the country in comparison to 17% of nation's rivers modified by more than 75,000 large dams (US Fish and Wildlife Service, 2017). While the primary objective of the policy is to protect the “outstanding values”, recreationists can still enjoy a variety of outdoor recreation activities in those rivers which are further classified as wild, scenic, and recreational based on the level of impoundment and accessibility to the river. Non-motorized boating activities (e.g., boating, canoeing, kayaking, tubing, rowing, and rafting) are one of the most popular recreational use of these rivers, and hence the focus of this study. Throughout the remainder of the paper, non-motorized boating is used as a general term for all non-motorized boating activities. This study investigated only the non-motorized boating within the national forests and grasslands managed by the USDA Forest Service (USFS) which is one of the four primary federal agencies responsible for management of WSR in federal lands along with the National Park Service, U.S. Fish and Wildlife Service, and Bureau of Land Management. The national forests and grasslands are considered the largest source of public

outdoor recreation opportunities in the United States (USDA Forest Service, 2017a) and include more than half (122) of the WSR nationally as of June 2016 (USDA Forest Service, 2017b).

While looking at participation in non-motorized boating, Cordell (2012, p.35-40) reported that a large number of Americans had been historically participating and the rate of participation has been continuously increasing for many activities. He reported that more than 20% of Americans participated in some form of non-motorized boating in 2005-2009 and more specifically, among the individuals 16 or older, 9.7% canoed, 7.9% rafted, 4.4% kayaked, 4.4% sailed, and 4.0% rowed in 2005-2009. The participation in some of these activities has been forecasted to increase in the future (Bowker et al. 2012; White et al. 2016). For example, White et al. (2016, p. 7) projected an increase in floating activities (canoeing, kayaking, and rafting) of between 13.1% and 21.7% by 2030 from 39.8 million participants in 2008 depending on climate change scenarios. Similarly, Bowker et al. (2012, p. 26) projected the number of adults participating in floating to increase by up to 62% by 2060 under different climate change scenarios. While looking at 149 million annual visitors in the national forests, about 3.58 million visitors participate in those activities, and 1.64 million visits primarily for non-motorized boating (USDA Forest Service, 2015).

The national forests provide a wide range of environmental services and recreational opportunities to the American people, and the USFS invests considerable resources in managing these resources for recreational benefits. Those benefits should be measured to facilitate the assessment of recreation activities and evaluate the effectiveness of the management efforts. Many environmental benefits are typically not traded in competitive markets (Freeman, 1993)

although their cultural significance is generally understood. These benefits are usually difficult to quantify, and non-market economic valuation approaches are needed. Management decisions about natural resource recreation resources such as rivers may not be optimal without a proper valuation and accounting of all river use (Loomis & McTernan, 2014). Contingent valuation (CV) and travel cost methods (TCM) are commonly used stated (based on data individual's response to hypothetical questions) and revealed (based on individual's actual behavior data) preference methods, respectively to value the non-market benefits. In particular, TCM is the most commonly used method for valuing access to recreational sites (Parsons, 2003).

Numerous studies have examined the economic value of accessing individual rivers for non-motorized boating (Bowker, English, & Donovan, 1996; English & Bowker, 1996; Johnson, Shelby, & Bregenzer, 1990; Siderelis, Whitehead, & Thigpen, 2001). However, only two travel cost method (TCM) studies have analyzed the value of and demand for non-motorized boating using national level river data (Bergstrom & Cordell, 1991; Bowker et al., 2009), and the generalizability of the results is limited. For example, Bergstrom & Cordell (1991) analyzed the data collected from more than 200 sites in national parks, recreational areas, and national forests using zonal TCM which ensures lesser statistical efficiency and is therefore considered less precise than the individual TCM. Bowker et al. (2009) estimated the aggregate economic value of non-motorized boating along with other recreational activities such as bicycling and horseback riding. Considering a large number of non-motorized boaters in the national forest annually, credible and broadly applicable information on what factors influence the demand for and value of recreational access for non-motorized recreation, and how river designation status and other

river characteristics impact demand, as well as, the value is needed. To fill this knowledge gap, this study has three specific objectives.

The first objective is to estimate the demand for and net economic value of non-motorized boating in the U.S. national forests. By utilizing boaters' data for all the national forests from all over the country between 2005 and 2014, the study represents the most extensive study of its kind ever undertaken in the United States. Since previous studies have a limited scope for generalizing the results because of multiple reasons such as small sample size, arguably less robust method (Bergstrom & Cordell, 1991) compared to individual TCM, this study fills an information gap by providing results generalizable to the national outdoor recreation industry. The estimated value will better inform managers and planners about overall benefits of managing non-motorized boating in national forests. In addition, valuation of benefits will help to set management priorities to promote river recreation in the future, and the value can be used for the cost benefit analysis of river management projects.

Emerging literature on the value of designation shows that official designation of land-based recreation sites affects site visitation and the local economy (Cline, Weiler, & Aydin, 2011; McCool, 1985; Weiler, 2006; Weiler & Seidl, 2004). Weiler and Seidl (2004) found a positive impact of changing a national monument's designation to a national park on visitation. They also showed the new designation as national park brought more economic impact in the region than before. In a study of eight national parks, Weiler (2006) concluded that designation signals are credible in increasing the visitation and these signals are mainly important to distant visitors who have imperfect information on site characteristics compared to more proximate

visitors who are more familiar with the site. It is hypothesized that designation could enhance the recreation appeal of a given site and help increase visitors' interest (Weiler & Seidl, 2004). The increase in visitors could be result of combination of multiple factors: increased promotion or public awareness of the site (Palmer, 1993; Weiler, 2006), and perceived differences in the availability as well as quality of services (Weiler & Seidl, 2004).

The second objective of this study is to investigate whether there is a difference on the demand for and economic value of non-motorized boating between designated and non-designated rivers. Among many of the congressional designations, WSR aims to protect the natural integrity and recreational value of natural rivers in the United States (USDA Forest Service, 2017c). Under the WSRA, more than 1.4 million acres of the riparian ecosystem in the form of wetlands and upland forests are currently protected (Chesterton, 2017). One of the primary goals of the WSRA is to maintain the free-flowing condition of rivers which could directly affect the desirability of recreation activities (Keith et al., 2008; Moore & Siderelis, 2002). Along with preserving the river itself, the designation can also provide many benefits such as recreation, biodiversity and other ecosystem services (Bowker & Bergstrom, 2018). Although promoting economic growth or increasing visitation is not the primary objective of the act, maintaining the free-flowing condition of the river could protect recreational qualities which ultimately increase the recreational appeal as well as economic value to many river activities. The impact of the designation on demand and economic value has been a subject of relatively few studies, and they have focused on individual rivers or their parts (Moore & Siderelis, 2002; Moore & Siderelis, 2003; Palmer, 1993; Walsh, Sanders, & Loomis, 1985) and none of the

studies has provided an aggregate value of recreation access to the whole WSR system (Bowker & Bergstrom, 2018, Keith et al., 2008). While the effect of public designation such as national park or, wilderness has already been tested, previous studies have not linked WSR designation to recreation activities (Keith et al., 2008), except guided whitewater rafting (Bowker et al., 1997). They reported a significant and positive effect of designation on economic value for a sample of rafters using trip data from five rivers including two designated rivers. Although they found that price response and the net benefit are likely affected by designation, their results cannot be generalized because of the small sample size. The significance of WSR designation is either unknown or misunderstood although it is considered one of the nation's strongest forms of protection of free-flowing rivers (Chesterton & Watson, 2017). Therefore, the current study attempts to address this gap by using nationwide river visitation data and provides statistical evidence of designation signaling regarding demand for and economic value of non-motorized recreation.

The third objective of this study is to examine the effect of site and river flow characteristics on the demand of non-motorized boating in national forests. It is understood that site attributes affect the demand for recreation activities (Murdock, 2006; Vaughan & Russell, 1982). Vaughan and Russell's (1982) fishing study found that estimates can be biased if site characteristics are not included in travel cost parameter and welfare estimation. Similarly, Murdock (2006) found that economic benefits are likely affected by site characteristics, supporting their inclusion in the demand model. While some of the studies have included few river or site characteristics in their models (Bowker et al., 1997; Boyer, Melstrom, & Sanders,

2017; Boyles et al., 1993; Daubert & Young, 1981; Loomis & McTernan, 2014; Siderelis & Moore, 2006; Ward, 1987), none included all the important site and river characteristics in a single demand model. Bowker et al. (1997), for example, showed the importance of incorporating site factors such as designation and floating time which had a significant effect on price response and net economic benefits. Using river flow and site characteristics data in combination with trip data collected from a nationwide on-site survey of river recreationists is another unique feature of this study. The understanding of the structure of non-motorized boating demand allows managers and planners a better understanding of potential market shifts from changes in site and river characteristics demand (Zawacki et al. 2000).

This study is timely, especially considering the fact that this year marks the 50th anniversary of the WSRA and there is considerable interest among stakeholders in evaluating the benefits of designation. The results of this analysis will facilitate the assessment of management efforts for designated rivers by federal agencies and organizations such as the Wild and Scenic Rivers Council, the American Rivers, and the River Management Society.

3.2 Previous studies

3.2.1 Demand for and economic value of non-motorized boating

The TCM, one of the commonly used revealed preference valuation methods, is used to estimate the net economic value of recreation access (Haab & McConnell, 2002; Parsons, 2003). It is a demand-based model for recreational use of a site or multiple sites (Parsons, 2003), where a number of trips taken by a recreationist (nonnegative integers) is modeled as a function of the

cost of accessing the site and other socio-demographic factors. The relationship between the trip demand and cost is exploited to estimate the net benefit from accessing the site. The welfare measure or the net benefit a recreationist derives by accessing the site is expressed in terms of net economic benefit or consumer surplus (CS). It is the difference between how much a recreationist is willing to pay and the actual cost s/he incurs in accessing the site (Freeman, Herriges, Kling, 2014). Several assumptions must be addressed within the data in order for the valuation measures from TCM to be considered valid (Haab & McConnell, 2003). The travel and time cost to a site is a proxy for the price of a recreational trip, and the cost of travel must be incurred for a single destination trip for the sole purpose of recreation, as multipurpose and multi-destination trip cost is difficult to calculate. In addition, travel time is neutral suggesting no utility or disutility from the travel time.

Within the whitewater recreation literature, various valuation approaches were used for welfare analysis of non-motorized river recreation, but a majority of studies aggregated multiple recreation activities and estimated the overall welfare for outdoor recreation activities along with non-motorized boating (Bowker et al. 2009; Boyer, Melstrom, & Sanders, 2017; McKean, Johnson, Taylor, & Johnson, 2005; McKean & Taylor 2000; McKean, Johnson, & Taylor, 2003; McKean et al., 2005; Treiman, Sheriff, Renken, & Loomis, 2013). A review of recreation valuation studies by Rosenberger (2016) found that non-motorized boating studies mainly used either TCM or CV method or a combination of both approaches to estimate the economic value of recreation access.

In a recent database of 421 recreational use value studies, Rosenberger (2016) reported 87 estimates from 25 different studies of non-motorized boating from 1977 to 2014. Most of the estimates (68) were for whitewater boating such as Bowker, English, & Donovan (1996); English & Bowker (1996); Johnson, Shelby, & Bregenzer (1990); Siderelis, Whitehead, & Thigpen (2001), while the remaining were for non-whitewater activities. However, the database does not incorporate all existing studies on the recreational value of non-motorized boating such as, Moore & Siderelis, 2002; Moore & Siderelis, 2003; Ready & Kemlage, 1998; Walsh et al., 1985. Bowker, English, and Donovan (1996) examined per trip CS associated with guided rafting on Chattooga and Nantahala River, two representative rivers of different rapid class in the southern United States, and found the magnitude of the net benefit from visiting these rivers depends on river quality and the modeling assumptions regarding opportunity cost of time. Most of the studies on demand and recreation value of non-motorized boating are dated, the most recent one is Loomis and McTernan (2014), which found the per person per trip value of instream flow to non-commercial paddlers in Poudre River, the only Wild and Scenic River in Colorado, to be \$115. As reported in Rosenberger (2016), there is tremendous variation in the CS estimates among the studies as the economic value of non-motorized boating depends on many factors including study methodologies, assumptions, sampling methods, type of activities, the location of river, site characteristic, and river features.

Within the recreation valuation literature, Bergstrom and Cordell (1991) is the only study to estimate an economic value for non-motorized boating on a national scale. The authors developed demand equations and estimated the combined economic value of river recreation

activities such as rafting, tubing, canoeing, kayaking, and boating by using zonal TCM, which is considered a less robust modeling approach than individual TCM. While Bowker et al. (2009) also used national level NVUM Round 1 data to estimate the net economic value of 14 different outdoor recreation activities in the national forests and grasslands, the welfare estimates for non-motorized boating were aggregated with other activities such as biking and horseback riding due to sample size restrictions. CV surveys have also been used to assess the economic value of non-motorized boating (e.g., Boyle, Welsh, & Bishop, 1993; Daubert & Young, 1981; Loomis, 2005; Loomis & McTernan, 2014; Siderelis, Whitehead, & Thigpen, 2001; Walsh, Sanders, & Loomis, 1985). The CV study on kayakers and rafters by Loomis and McTernan (2014), for example, found a willingness to pay of \$62 to \$108 depending on the instream flow of the river. They found similar economic value estimations in the TCM and CV method, confirming some consistency in both methods, and a level of convergent reliability. In a similar CV study, Boyle, Welsh, and Bishop (1993) estimated willingness to pay values under different water flow conditions for Grand Canyon whitewater boaters. Using a CV survey in eastern North Carolina, Siderelis, Whitehead, and Thigpen (2001) estimated the paddler's willingness to pay and concluded that adding annual fees does not affect their demand.

3.2.2 Effect of river designation

The existing literature does not show unambiguous results of designation effect on recreational demand. Some of the studies have shown a significant effect of designation (Loomis, 1999; Weiler, 2006; Weiler & Seidl, 2004) while others have not found any designation effect (Buckley, 2004; McCool, 1985; Rodwell, 2002). Using 1979-2000 data,

Weiler and Seidl (2004) found a significant and positive effect of national park designation on recreation visitation. In contrast, the “before and after designation” analysis by McCool (1985) did not find an increase in recreation use, as the percentage of first-time visitors to Rattlesnake National Recreational and Wilderness Area decreased after designation. However, WSR designation is different from wilderness designation which provides the highest level of protection for federal lands. While the goal of wilderness designation is to protect wilderness areas in their natural condition, the WSR designation aims to maintain the free-flowing condition and to preserve outstanding values of the rivers and their immediate environments.

The impact of WSR designation on recreational demand has not been studied widely, and none of the studies has attempted to study changes in economic value due to designation (Bowker & Bergstrom, 2017; Keith et al., 2008). The ideal approach to examine the designation effect is to assess the economic value before and after the designation to quantify the net changes, but there has not been such study so far (Keith et al., 2008). Walsh et al. (1985) surveyed 214 Colorado residents about 11 rivers recommended for designation and found that the majority of residents would support designation where their support for designation was driven by ecological (e.g., water and air quality, fish habitat) and bequest value. The residents’ willingness to pay for protecting the river through designation was \$45 per household, and the marginal benefit was higher than proposed marginal management cost of each river suggesting the economic profits from the designation. Palmer (1993) reported the river managers’ survey conducted in 1975 which found increased recreation visits on both designated and undesignated rivers. He further gave examples of rivers in Pennsylvania, Ohio, Idaho, and Oregon where the

non-designated river has higher recreation visits compared to the designated river, but he did not provide any scientific proof for the results. His results suggest that designation might not affect the demand but other factors such as recreational suitability, publicity of the site, and marketing strategies along other federal regulation could play an important role in determining visitation in the rivers (Keith et al., 2008). Bowker et al. (1997) studied the guided river rafting in five rivers including two designated rivers: Chattooga and Middle Fork River. Using a pooled truncated negative binomial model, the authors found that price response and CS were affected by river characteristics such as designation and floated distance in their study. However, the interaction of designation and TC variable was found insignificant when the subsamples with either of the two designated rivers were tested suggesting potential sample size issues such as lack of dispersion over sample space. However, they did not test the effect of designation on autonomous demand.

Although the designation signals are credible and significant in the case of national parks (Weiler, 2006), there have been conflicting reports of the awareness level of WSR designation (Moore & Siderelis, 2003; Moore & Siderelis, 2002). Moore and Siderelis (2002) reported that more than half (53%) of the users of the Farmington River were unaware that the river was designated, although it had been a WSR for nearly seven years. In contrast, a majority of the users (83%) of the Chattooga River users were aware of the river's designation (Moore & Siderelis, 2003). It is important that recreationist knowledge about the designation of a site could motivate them to visit the site. As mentioned by Weiler (2006) and Weiler and Seidl (2004), distance could be the factor because local visitors living near the river are less likely to care

about the designation status. Although both the studies did not examine the impact of designation, users in both rivers thought that designation is important in preserving and protecting the river quality.

Previous studies have examined the economic impact of designation (Moore & Siderelis, 2002; Malm, 2012; Walsh et al. 1985). Moore and Siderelis (2002) is the only study to assess the effect of designation to adjacent property values and found that the property value is inversely related with distance from the river, suggesting the amenity value of proximity to rivers. However, they did not find a significant effect of the Farmington River's designation status on property values. Analyzing the per capita income data of county-level data of the lower 48 states from 1970-2009 using quasi-experimental approach, Malm (2012) found the designation has a negative impact on county-level per capita income (0.3% points) in the short-run (up to 15 years), but the impact diminishes in the long run due to changes in the socio-economic composition and the presence of industries.

Very few TCM studies have assessed recreation value of WSRs in the United States (e.g., Bowker et al., 1997; Bowker et al., 1996; Walsh, Sanders, and Loomis, 1985), but none of those studies compared the economic values between designated and non-designated rivers. Bowker et al. (1996) and Bowker et al. (1997) estimated the recreational benefits of both designated and non-designated river, but they did not compare the economic value. Though the designated river has higher economic values compared to non-designated, the difference has not been linked to designation systematically. The higher economic value could be due to physical characteristics and other factors associated with river recreation than designation effect.

3.3 Methods

3.3.1 Theoretical model

The travel cost model is a demand model for ecosystem services of a recreational site (Haab and McConnell, 2002), variation in the number of trips as well as the cost of travelling to the recreation site is the basis for estimating the demand for accessing recreation site(s) (Freeman, Herriges, Kling, 2014). It assumes that the costs of traveling by an individual or group to the recreation site from their origin are a proxy price for the value placed on accessing recreational opportunity of the site (Boxall, McFarlane, & Gartrell, 1996). In TCM, the empirical process of estimating net economic benefits involves two steps: (i) the estimation of parameters of the demand function and, (ii) the calculation of the welfare measure from the estimated parameters (Haab & McConnell 2002, p. 159). Following Freeman (1993, p. 443-447), the travel cost is based on actual behavior reflecting utility maximization subject to constraints and the utility maximization function can be represented by,

$$\text{Max: } u(X, R, Q) \quad (3.1)$$

s.t.

$$M + P_W * T_W = X + C * R \quad (3.2)$$

$$T^* = T_W + (T_1 + T_2) * R \quad (3.3)$$

Where, the utility is a function of goods or services, X , the number of visits to the recreation site, R , and environmental quality of the site, Q . The utility function is subject to money (M) and time (T^*). The sum of exogenous income M , and product of wage rate (P_w) and hours worked (T_w) is equal to the sum of amount of goods purchased and the product of number of recreation visits to the site, R , and the monetary cost of the visit, C . The sum of time spend on two-way travel (T_1) and time spent on the site (T_2) multiplied by the frequency of visits (R) plus the amount of working time (T_w) is the total discretionary time.

As Haab and McConnell (2002, p. 144) suggested, the utility maximization equation subject to the constraints can lead to the general demand function:

$$Y = f(C, S, H, Q) \quad (3.4)$$

where Y is the number of trips demanded, C is the cost associated with a trip to the recreation site, S is the cost associated with a trip to the substitute site, H is the vector of individual's socio-demographic factors, and Q is the vector of qualities of the site. It is a single site demand function, and it does not adequately capture the complexity of recreation behavior in the multi-site setting where models are estimated as a system of demand equations (Freeman 1993, p. 455). To address the difficulty of estimating a number of demand equations for multi-site models, Freeman (1993, p. 456) suggested to pool the data across sites and treat all visits of individuals to multiple sites as belonging to a single demand equation as follows:

$$Y_{ik} = f(C_{ik}, S_{ik}, H_i, Q_k) \quad (3.5)$$

where Y_{ik} is the number of trips taken by individual i to visit site k , C_{ik} is the cost of individual i trip to site k , S_{ik} is a cost related to visit substitute of site k for individual i , H_i vector of socio-demographic measures of site i , and Q_k is the vector of qualities of the site k .

The dependent variable, number of visits, is a non-negative integer in the demand function and it is estimated as a count data model (Parsons, 2003). The ordinary least-square regression is not appropriate for estimating the model and the basic approach to satisfy the count data is to employ Poisson regression (Parsons, 2003). Since few recreationists usually make many trips and many make few trips on recreational trips, the trip variable is over-dispersed i.e., the mean and the variance are not equal. Therefore, a negative binomial model is used instead of Poisson because Poisson estimator underestimates the standard errors and inflates the t-statistics though it is still consistent (Amoako-Tuffour & Martínez-Espíñeira, 2012).

Non-negative integer count, truncation, and endogenous stratification are well-documented problems in on-site survey data while analyzing the demand model (Martínez-Espíñeira & Amoako-Tuffour, 2008; Parsons, 2003). Since non-visitors are not observed during the on-site survey, the depended variable is truncated at zero i.e., it only takes an integer value higher than zero. Therefore, previous studies address the zero-truncated count data by using the truncated negative binomial model to avoid the issue of biased and inconsistent estimators (Creel & Loomis, 1990; Shaw, 1988). In addition, endogenous stratification occurs when the likelihood of respondents being surveyed is positively related to the frequency of their visits to the recreation site. The combined effect of truncation and endogenous stratification could result in inconsistent and biased estimation (Martínez-Espíñeira & Amoako-Tuffour, 2008). Englin and

Shonkwiler (1995) applied a truncated, endogenously stratified negative binomial model to address these issues and the model has been widely used in recreation demand studies with on-site data (Loomis & McTernam, 2014; Martínez-Españeira & Amoako-Tuffour, 2008). Due to this common criticism of mean-variance equality of truncated Poisson regression, Englin and Shonkwiler (1995) and Cameron & Trivedi (1998) introduced a parameter (α) which addresses the unexplained heteroscedasticity in the demand model which is constrained to zero in the Poisson model. Following Cameron and Trivedi (1998), the estimator for truncated negative binomial regression can be represented as:

$$Prob(Y = y|Y > 0)$$

$$= \left[\frac{\left(\tau \frac{y+1}{\alpha} \right)}{\tau(y+1)\tau\left(\frac{1}{\alpha}\right)} \right] (\alpha\lambda)^y ((1 + \alpha\lambda)^{-(y+\frac{1}{\alpha})}) [1 - F_{NB(0)}]^{-1} \quad (3.6)$$

with a conditional mean of

$$E(Y|X, Y > 0) = \lambda [1 - F_{NB(0)}]^{-1} = \left(\frac{e^\lambda}{1 - e^\lambda} \right) \quad (3.7)$$

Where λ is parameterized as $e^{X'\beta}$

3.3.2 Benefit calculations

The CS is defined as the area under the demand curve between the choke price and the individual's price line (Parsons, 2003), and the estimated parameters from the demand function can be used to calculate per trip CS. Mathematically, the surplus is equal to the negative inverse

of the estimated travel cost coefficient. The estimated coefficients from the equation (3.5) can be used to calculate the average per trip CS per group and CS per person per trip can be calculated by dividing it by the average number of people per group. The equation for CS is given by the equation (3.8).

$$CS = -\left(\frac{1}{\beta_{TC}}\right) \quad (3.8)$$

3.3.3 Data

Data on national forest visitors were obtained from the NVUM program of USFS which is conducted to estimate the volume of recreation use on national forests. The program started collecting data in 2000 with the goal of providing a science-based estimation of the volume and characteristics of recreation visitation to help the USFS manage its resources effectively (USDA Forest Service, 2007). While the primary objective of NVUM is to estimate the number of recreation visits annually to the National Forest System, a secondary objective is to obtain relevant details information from visitors such as demographics and trip characteristics (USDA Forest Service, 2017a). The authorized interviewers surveyed exiting visitors every year in 20% of 7,752 sites across the National Forest System through stratified random sampling and collected data on the trip profile, expenditures, satisfaction, and number of other variables (English, Kocis, Zarnoch, & Arnold, 2002). During the survey, respondents were randomly chosen when they exited the site after recreating the site and were leaving for the last time that day (English et al., 2002). When there was more than one person in a car or group, the person with the most recent birthday was selected to interview to avoid interviewer selection bias. The

survey collected a wide range of information on the visits including purpose of the visit, primary and secondary activities during the visit, annual number of visits for primary activity, time spent on site during the trip, number of people in the travelling group, substitute activities, location of recreation site and visitors' origin, trip expenditures, and socio-economic information. Details on NVUM sampling procedure can be found in English et al. (2002).

River and site characteristics variables were not available in the NVUM dataset. However, the physical locations (geographic coordinates) of the river where the visitors were exiting were available. Hence, for each of those sites, data on WSR designation status, river rapid classification, availability of ramp at the take-out point of the river, water discharge and velocity, and that information were collected from other sources that maintained spatially explicit information on river and site characteristics. The river designation information was available from www.data.gov which includes information on river length, designation types, and location (Data, 2017). Similarly, classification of rapid class (difficulty level) of each river was obtained from the Nationwide Whitewater Inventory (American Whitewater, 2017) which has a wide range of information on the rivers in the United States. The rapid levels were classified in the international scale from I (moving water with a few riffles and small waves) to VI (extremely dangerous and nearly impossible) rapid class for most of the rivers in the country. The information about camp size and ramp at the take-out point for each national forest site was available from the USFS website. Since the ramp availability information was not entirely available in USFS's website, additional information was obtained from www.boatus.com

(BoatUS, 2017) which has the physical address of more than 25,000 public and private boat launch locations.

Water discharge and velocity data of the rivers were obtained from the United States Geological Survey's (USGS) National Water Information System which is the principal repository of water resources data from more than 1.5 million sites for more than 100 years (United States Geological Survey [USGS], 2017). The USGS water surface data includes more than 850,000 station years of time series data including stream level, surface water quality, and rainfall. The mean water velocity in cubic feet per second and the water discharge in cubic feet per second of the river were obtained for nearby water stations from the interview site.

3.3.4 Empirical model

The sample unit for NVUM survey was a “group”, which can be a single person or a group of people travelling together. Following Sardana et al. (2016), the annual number of non-motorized boating trips by an individual or group was used as the dependent variable. The dependent variable was computed based on their responses to multiple questions. First, the respondent was asked about the recreation activities in which they participated during the trip and then, the respondent was asked to identify the “primary activity” for the current trip. Next, those who indicated non-motorized boating as primary recreation activity were asked to indicate the number of trips (including current trip) taken during the last 12 months for the primary activity mentioned.

Some adjustments were performed on the original NVUM dataset for theoretical and empirical reasons. Since there is no systematic method to parse out travel cost for individual activities in multipurpose and multi-destination trips (Parsons, 2003), a standard procedure in TCM was followed by only including the observations with non-motorized boating as the primary purpose of the visit (Loomis, Yorizane, Larson, 2000; Parsons, 2003; Sardana et al., 2016). Similarly, long-distance travel is likely to be multi-destination and multi-purpose which makes it difficult to separate economic value of individual activities. The long-distance traveler's decision-making is different from that of those traveling relatively short distance. Considering the difficulty of dealing with long-distance travel which probably includes air travel, observations with more than 1,000 miles in travel distance were trimmed, a procedure followed by numerous studies (Bin, Landry, Ellis, & Vogel song, 2005; Bowker, English, & Donovan, 1996; Heller setin, 1991). International visits and visits outside the conterminous United States were also dropped because the nature of these visits differs from the conterminous United States. In addition, a portion of international visits could be multi-purpose, and parsing out the cost for the non-motorized boating could be cumbersome if not impossible.

The observations with annual visits greater than 52 were censored, allowing one trip per week. Such censoring is typical in travel cost studies to avoid non-recreationist visitors such as fishing or boating guides (Bowker et al. 2009; Egan & Herriges 2006; Englin & Shonkwiler 1995; Sardana et al. 2016). Similarly, observations where the number of people traveling in the vehicle was reported more than ten were trimmed because it was assumed that recreationists in a

large group were from a different population than rest of the data and large-group travel could be a non-recreational trip.

Using the general demand function described in the equation (3.1), the empirical demand model for non-motorized boating to rivers in the national forests was specified as follows:

$$TRIPS_{ik} = f \left(\begin{matrix} TC_{ik}, SUB_{ik}, SE_i, PEOPVEH_{ik}, UNDER16_{ik}, DESIGNATED_{ik}, \\ RIVER_k, SITE_k, DAYS_{ik}, RECESSION, ROUND3 \end{matrix} \right) + \mu_{ik} \quad (3.9)$$

Where, $TRIPS_{ik}$ represents the annual trip taken by travelling group i to site k , TC_{ik} is the trip cost associated with individual or group i 's to river k , SUB_{ik} is the cost of travelling between individual or group i 's origin to the closest river other than river k , and SE_i represents socio-economic variables of the individual including age, gender, and estimated annual income, $PEOPVEH_{ik}$ is the number of people in the travel party, $UNDER16_{ik}$ is the number of people under sixteen in the travel party, $DESIGNATED_{ik}$ is the dummy variable if the visited river is designated, $RIVER_k$ are characteristics of the river k , $SITE_k$ are site characteristics at take-out point of the river k , $DAYS_{ik}$ is the number of days spent at the site during the current visit, $RECESSION$ is the dummy variable if the visits were during the recession or its aftermath, $ROUND3$ is the dummy variable if the visits were during $ROUND3$ of NVUM survey, and the term u_{ik} is random error.

Trip cost is the sum of the expenses required to make a trip including travel cost, equipment cost, access fees to the recreation site, and the opportunity cost of time (Parsons, 2003). Since the NVUM survey does not collect information on the mode of transportation and

type of a vehicle used during the visits, it was assumed that mode of transportation was only land. The CDXZipStream, an Excel add-in to analyze ZIP code data in Microsoft Excel, was used to calculate driving distance and time between the ZIP code of respondent's residence (i.e. the origin of the trip) and the river site where they were found recreating. Since the location information is required to calculate the travelled distance and cost of the travel, observations with the missing location of river site or ZIP code of respondent's home were dropped.

Following Parsons (2003), the mileage rate of the vehicles for the respective year was estimated by adding cost of gas and upkeep (such as cost of oil, maintenance, tires) for every year between 2004 and 2014 and following Knoche and Lupi (2007), the fixed costs such as insurance and depreciation cost were not included in the mileage rate. The average vehicle operating cost per mile of the medium sedan was \$0.175 (American Automobile Association [AAA], 2017). Estimating the cost of travel time is the most challenging issue in computing trip cost (Parsons, 2003), and there is still no consensus on treatment of time in travel cost studies (Martínez-Espiñeira & Amoako-Tuffour, 2008; Randall, 1994; Zawacki et al., 2000). The most commonly used practice is to value travel time at the full or a third of the hourly wage rate (Knoche & Lupi, 2007; Parsons, 2003; Phaneuf & Smith, 2005). Therefore, two travel cost variables were constructed based on two different assumptions regarding the opportunity cost of time involving in travelling (no opportunity cost of time, and a portion ($1/3^{\text{rd}}$) of wage rate as the opportunity cost of time). The first travel cost variable ($TC1$) was the product of round-trip driving distance and mileage rate, plus reported recreation fees. The second travel cost variable ($TC2$) was a sum of $TC1$ and opportunity cost of time. The opportunity cost of time was a

product of total time (hour) spent on two-way travel and $1/3^{\text{rd}}$ of wage rate (\$/hour). Per hour wage rate was imputed by dividing annual household income by a total number of working hours (2080) in a year (Loomis & McTernan, 2014). Trip cost usually includes access fees, equipment cost along with travel and time cost (Parsons, 2003). The entry fee and equipment cost may vary by weekend or weekday, half day or full day, and age of the recreationists and depend upon the availability of discounts such as complimentary ticket rates, promotional rate, pre-purchase deals, online ticket brokers, and package deals. The daily fee typically is used in travel cost due to the difficulty of accounting variation in the fees (Parsons, 2003). As Parsons (2003) suggested an alternative strategy for estimating access fees is to use the perceived cost information, reported entry fees (entry, parking, or recreation use fees), and equipment rental and guide fees available in NVUM data were used.

The NVUM survey collects the substitute information for only one-third of the respondents, and it only has information about substitute behavior rather than substitute site of the current site. It is suggested that substitute prices/goods should be included in the demand model (Parsons, 2003), the valuation of the site will be biased without substitute information (Rosenthal, 1987). Various substitute information have been used in the demand function in TCM such as price of visiting a substitute site (Cho et al., 2014; Sardana et al., 2016), number of trips to substitute site (Loomis & McTernan, 2014), substitute index (Bergstrom & Cordell, 1991), and a dummy variable to define visitors intention to visit substitute site (Bowker & Leeworthy, 1998; Martínez-Espiñeira & Amoako-Tuffour, 2008). A heuristic rule was used to

assume the nearest river (from the origin) not visited for that particular trip to be a proxy for substitute site and calculated the two-way cost of accessing that site.

The NVUM data did not have income data for complete observations because only one-third of the respondents were asked the questions from the economic module. Following Mingie, Poudyal, Bowker, Mengak, and Siry (2017) and Kim, Shaw, and Woodward (2007), income² was estimated as a proxy to the annual household income of all the observations to use as many observations as possible but also minimize the potential bias due to missing income by using a log-linear ordinary least squares regression of household income on gender, age, number of people under 16 in the travelling group, and adjusted gross income from Internal Revenue Service (Regression results: $\ln(\text{estimated household income}) = 9.109 - 0.029 (\text{respondent being a male}) + 0.000003 (\text{IRS's gross income}) + 0.074 (\text{age}) - 0.0006 (\text{square of age}) + 0.01 (\text{number of people under 16 in the travelling group})$, $R^2 = 0.23$, $N=944$). The adjusted gross household income was obtained from Internal Revenue Service for the respondent's ZIP code for the respective year.

² The models with original income variable, which is available to one-third of the data, were estimated and the sign and magnitude of coefficient of income and other variables were consistent with the models using estimated income. For brevity and minimizing the bias due to missing income, only the models with estimated income is presented in this paper.

Inclusion of site characteristics is common in outdoor recreation demand modeling (Adamowicz et al., 1997; Creel & Loomis, 1990; Englin & Shonkwiler, 1995) but few studies have included the river and site characteristics in the demand model within the non-motorized boating studies (Boyles et al., 1993; Boyer et al., 2017; Daubert & Young, 1981; Loomis & McTernan, 2014; Siderelis & Moore, 2006; Ward, 1987). However, site and river characteristics expected to affect the demand and economic value such as instream flows, velocity, level of difficulty, and designation status has not been included in a single demand model. River flow is one of the most studied characteristics in recreation literature (Boyles et al., 1993; Boyer et al., 2017; Daubert & Young, 1981; Loomis & McTernan, 2014; Siderelis & Moore, 2006; Ward, 1987), but only a few studies have assessed the effect of river flow characteristics on the demand and economic value of non-motorized boating. Grossmann (2011) found that variation in the water navigability affects the boating demand, and water level and velocity in the river could affect the navigability. Therefore, both instream water level and stream velocity were included in the demand model. Sutherland (1982) suggested boat ramp is a proxy for a combination of factors that are indicators of attractiveness and accessibility of the river such as water quality, and acres of water. The river rapid classification has previously been used in river demand studies to represent the level of difficulty and adventure (Bowker et al. 1997). River and site characteristics along with designation data were combined with NVUM survey data in ArcGIS 10.5.1 utilizing its Network Analyst extension and individually verified. Since the rapid class information was not available for every respondent, it was assumed that those rivers without rapid level information had class I rapid level. Their rapid class inventory was based on different reports, so there may be some differences in rating standard used in assigning river difficulty.

Many aspects of TCM have been debated including on-site time (Amoako-Tuffour & Martinez-Espineira, 2012; Landry & McConnel, 2007) which is a source of utility as well as cost in demand (Acharya, Hatch, & Clonts, 2003). Freeman, Herriges, and Kling (2014, p. 300) mentioned that on-site time should theoretically be included in the demand function, and on-site time becomes constant only if all visitors choose visits of the same duration and if they all have the same opportunity cost of time (McConnell, 1992). Similarly, Acharya et al. (2003) found that excluding on-site time from demand function would result in biased estimation (i.e. smaller price effect, and larger CS). For this reason, following previous studies (e.g., Acharya et al. 2003; Amoako-Tuffour & Martinez-Espineira, 2012; Martinez-Espineira & Amoako-Tuffour, 2008; Melstrom, 2014; Shresthat et al., 2002), the number of days spent during the trip was included in the demand model. Similarly, a dummy variable to represent two different NVUM data rounds were included in the demand model to control for differences in the demand between two data collection cycles.

The data for the analysis were collected between 2005 and 2014 (Round 2 and 3 data from NVUM survey). A total of 3,917 respondents indicated that they have participated in non-motorized boating as the primary purpose of their visit. The observations which did not have nearby USGS water-data sites (1,267), and had missing data on water discharge (457), water velocity (212) and location of river site or ZIP code of respondent's home (183) were dropped. After trimming the observations (travelling distance more than 1,000 miles, travelling group more than 10, total annual visits more than 52, and dropping observations with missing values of

important variables, a total of 1,252 observations were available for final analysis³. While summarizing the final observations available, average annual number of trips to the river was just over five. On average, the cost of two-way travel between respondent's home and river ranged from \$228 to \$316 depending upon the assumptions about the opportunity cost of time. In terms of WSR designation, about one-third (37%) of visits were to designated rivers. The one-way distance from respondent's home to river site, on average, was 184 miles.

The definitions and descriptive statistics of the variables used in the model are reported in Table 3.1. The number of trips in a year, represented by *TRIPS*, taken by river recreationists within a year was modeled as the dependent variable of the demand model. The explanatory variables include two travel cost alternatives (*TC1* and *TC2*) as described above,

³ After dropping the missing values of important variables such as ZIP codes of respondent's home and river sites and observations with travelling distance more than 1,000 miles, the remaining observation were 3,108. After dropping missing data on important variables, the observations were reduced to 1,237 for final analysis. The mean values of important variables were not significantly different between the original and trimmed data for final analysis. Similarly, the sign of important variables were the same in the cases except in the DESIGNATED dummy, which was found negative in the full model but positive on the final model. However, it was found statistically insignificant in both cases. One of the reasons to have different sign in DESIGNATED dummy is the river sites where water measurements (discharge, velocity) were taken could be popular places and water data was measured on those places. Those places with missing values or no water measurements stations could be less popular river sites where demand could likely to be less. Similarly, per person net economic benefits were also not significantly different in the initial and final model.

Table 3. 1 Definition, and descriptive statistics of variables used in travel cost model of non-motorized boating trips to U.S. national forests (N=1,252)

Variable	Definition	Mean	Std. Dev.	Min	Max
TRIPS	Annual trips by respondent to national forest for non-motorized boating	5.6	9.4	1	52
Travel cost and socio-economic					
TC1	Travel cost with no opportunity cost of time assumed	126.7	120	0.4	582.5
TC2	Travel cost with opportunity cost based on 33% of wage	203.2	185.7	0.7	1190.2
TC1SUB	Travel cost with no opportunity cost of time assumed to visit the nearest river not visited from the origin	24.7	23.3	0.1	175.3
TC2SUB	Travel cost with opportunity cost based on 33% wage to visit the nearest river not visited from the origin	101.2	,97.9	2.9	775.8
INCOME	Estimated mean annual income	86,270.9	29,265.2	24,349.4	177,287.2
AGE	Age of the respondent	43	13.7	16	75
MALE	Dummy variable, 1 if the respondent was male, 0 otherwise	0.66	0.5	0	1
PEOPVEH	Total number of people in the travelling group during the trip	2.93	1.6	1	10
UNDER16	Number of people under 16 in the travelling group	0.49	1	0	9
Designation					
DESIGNATED	Dummy Variable, 1 if the river was designated, 0 otherwise	0.36	0.5	0	1
TC1DESIGNATED	Interaction term between DESIGNATED and TC1	125.1	113.7	0.36	575.8
TC2DESIGNATED	Interaction term between DESIGNATED and TC2	216.3	200.9	0.75	1190.2
Site and river characteristics					
LAKE	Dummy variable, 1 if there was lake within 1 mile of the river section, 0 otherwise	0.37	0.5	0	1

Table 3. 1 Contd.

Variable	Definition	Mean	Std. Dev.	Min	Max
RAPID4	Dummy variable, 1 if there was at least one rapid level equal or higher than level IV in the river section, 0 otherwise	0.41	0.5	0	1
RAMP	Dummy variable, 1 if boat ramp was available at take out point , 0 otherwise	0.51	0.5	0	1
CAMPSIZE	Number of camps at take-out point	3.83	10.5	0	93
DISCHARGE	Mean discharge in cubic meter per second	39.74	89.5	0.002	865.7
VELOCITY	Mean water velocity in meter per second	0.59	0.3	0.07	1.7
Other					
DAYS	Number of days spent during trip	1.77	1.8	1	35
RECESSION	Dummy variable, 1 if the year of the interview was between recession and aftermath period (Dec 2007- Dec 2010), 0 otherwise	0.28	0.4	0	1
ROUND3	Dummy variable, 1 if respondent was surveyed in Round 3 (2010-2014), 0 otherwise	0.54	0.5	0	1

costs required to travel the nearest river not visited in the current trip from respondent's home (*SUB1* and *SUB2*), estimated household income (*INCOME*), a binary variable if the respondent is a male (*MALE*), and, the age of the respondent (*AGE*). Other variables include a number of people in the travelling group or vehicle (*PEOPVEH*), number of people under 16 in the trip (*UNDER16*), a binary variable representing whether the respondent visited a designated river (*DESIGNATED*), and an interaction term between travel cost and designation dummy (*TCDESIGNATED*). The river and site-related variables include a dummy variable if there is a lake within a mile of interview site (*LAKE*), a dummy variable if there is at least one rapid class of 4 or higher on the river (*RAPID4*), a dummy variable if there is a boat launch or ramp at river take-out point (*RAMP*), number of campsites on the site (*CAMPSIZE*), water discharge in cubic meters per second (*DISCHARGE*), and water speed in meters per second (*VELOCITY*). Other variables in the demand function include a number of days spent during the non-motorized boating trip (*DAYS*), if the interviews were taken during recession or its aftermath (*RECESSION*), and a binary variable representing whether the interviews were taken during Round 3 (2010-2014) of NVUM survey (*ROUND3*).

3.4 Results and discussion

3.4.1 Regression estimates

Regression estimates of the trip demand model are presented in Table 3.2. Both the zero-truncated Poisson and negative binomial models were estimated, only the results from the latter are reported.

Table 3. 2 Regression estimates from alternative models of non-motorized boating demand at U.S. national forests, by alternative assumption of wage rate (N=1,252)

Variables	No wage rate	33% wage rate
Travel cost and socio-economic		
TC1	-0.0052** (0.0008)	-
TC2	-	-0.0039** (0.0008)
TCSUB	-0.012** (0.003)	-0.0006 (0.001)
INCOME	0.00001* (0.000002)	0.00001** (0.000002)
AGE	-0.014** (0.005)	-0.016** (0.005)
GENDER	0.37** (0.11)	0.342** (0.11)
PEOPVEH	-0.128** (0.04)	-0.139** (0.04)
UNDER16	-0.049 (0.07)	-0. (0.07)
Designation		
DESIGNATED	0.1001 (0.18)	0.091 (0.18)
TCDESIGNATED	-0.0013 (0.001)	-0.00003 (0.0009)
Site and river characteristics		
LAKE	-0.45** (0.13)	-0.354** (0.12)
RAPID4	0.418** (0.12)	0.458** (0.12)
RAMP	0.411** (0.12)	0.294* (0.12)
CAMPSIZE	-0.012*(0.005)	-0.013*(0.005)
DISCHARGE	0.00002 (0.0006)	0.0001(0.007)
VELOCITY	-0.648* (0.27)	0.589* (0.27)
Other		
DAYS	-0.152** (0.05)	-0.126** (0.05)
RECESSION	-0.024 (0.14)	0.043 (0.14)

Table 3. 2 Contd.

Variables	No wage rate	33% wage rate
ROUND3	0.206* (0.12)	0.211* (0.12)
INTERCEPT	-16.07** (0.65)	-16.88** (0.12)
LOG-LIKELIHOOD VALUE	-697.4	-700.6
AIC STATISTICS	1434.8	1441.1

Note: ** and * indicates statistical significance at $\alpha = 0.01$ and $\alpha = 0.05$ level, respectively, and numbers in parentheses are standard errors.

This is because the likelihood-ratio test of over-dispersion rejected the null hypothesis that the mean and variance of the dependent variable are equal, justifying the use of negative binomial model over Poisson regression. The negative binomial model also had lower Akaike Information Criteria (AIC) statistics than the Poisson⁴. For brevity, only the models with recreational fees are presented in the paper. The sign of most of the variables was consistent with economic theory except for *SUB*, and all the coefficients were significant at either 5% or 10% significance level except for *DESIGNATED*, *TCDESIGNATED*, *UNDER16*, *SUB*, *RECESSION*, *ROUND3*, and *DISCHARGE*.

3.4.2 Travel cost and socio-economic variables

The estimated coefficient for travel cost was significant at $p < 0.05$ and negative as expected in both models of the alternative cost of time assumptions. This suggests that demand for non-motorized boating decreases with increased travel cost. The negative relationship between demand and the price of the travel is in line with the economic theory of demand and is consistent with previous river recreation studies (Bergstrom & Cordell, 1991; Bowker & English, 1994; Bowker, English, & Donovan, 1996; Loomis, 2003; Hellerstein, 1991; Loomis & McTernan, 2014; McKean, Johnson, Taylor, & Johnson, 2005). The substitute variable (*SUB*)

⁴ The models with and without recreational fees in the travel cost variables were also estimated but the sign and magnitude of the coefficient was essentially the same in both models. For brevity, only the models with recreational fees are presented in the paper.

was found to be significant at $p < 0.05$ only in the model that does not consider the opportunity cost of time in travel cost. The negative sign of substitutes appears counter-intuitive suggesting recreationists living close to the rivers (substitutes sites) are likely to take fewer trips to the rivers or these nearby rivers could not be attractive as rivers in the national forests. As every recreation activity is a unique and each recreationist has unique preference regarding the use of leisure time, there is no simple solution as to how to select a substitute for an outdoor recreation activity as pointed out by Freeman (1993, p. 454). The literature on recreation demand shows mixed findings regarding substitute variables, ranging from negative (Bowker, English & Donovan, 1996; Loomis & McTernan, 2014) to insignificant (Amoako-Tuffour & Martínez-Espiñeira, 2012; Cho et al., 2014) to positive (Bowker, English, Bergstrom, 1997; Sardana et al., 2016) effect of variable used to represent substitute's effect. While analyzing the substitute information available in about one-third (32%) of the NVUM data, only about 47% respondents would go to the substitute site river recreation if the site for their current national forest visit were unavailable. Other substitute choices in the NVUM survey included staying at home (16%), coming back another time for river recreation (16%), going somewhere else for another activity (15%), going to work (3%), and others (4%). Although these data are only available for one-third of the sample, they suggest that simple substitution variables, commonly used in TCM may be problematic given the complex nature of recreation behavior.

The positive and significant at $p < 0.05$ sign of income (*INCOME*) suggests that demand for non-motorized boating increases with higher annual household income. This observation is in line with results reported by many river recreation studies (Bergstrom & Cordell, 1991; Bowker

& English, 1994; Bowker, English, & Bergstrom, 1997; Hellerstein, 1991; Johnson, Shelby, & Bregenzer, 1990) although other studies had found contrasting results about effect of income on recreation demand (Loomis, 2002; Loomis, 2003; McKean, Johnson, & Taylor, 2012; Smith & Moore, 2013). The coefficient on age (*AGE*) was negative and significant at $p < 0.05$, suggesting older recreationists are likely to take fewer trips than their younger counterparts, considering the effect of all other factors constant. It should be reiterated that only individuals over 16 were interviewed during the NVUM survey. This result seems intuitive since non-motorized boating is physically challenging which requires a higher level of skills, energy, fitness, and quick decision-making capacity, compared to other outdoor activities such as fishing, swimming, and sightseeing. The results are in line with previous studies on river recreation valuation (Loomis & McTernan, 2014; Loomis, 2003; McKean, Johnson, & Taylor, 2012).

The positive coefficient on male (*MALE*) at $p < 0.05$ suggests that males on average are likely to take more visits than females. Similar findings regarding gender preferences in outdoor recreation participation have been reported elsewhere in river recreation demand studies (Eiswerth et al., 2000; Loomis, 2003). Although males commonly have a higher demand for many outdoor recreation activities than females, this may not always be the case. For instance, Loomis and McTernan (2014) found higher trip demand for female kayakers than male but their study was only limited to non-commercial kayakers in the Poudre River, Colorado and their conclusion may not be generalized. The negative and significant coefficient on a number of people traveling in the group (*PEOPVEH*) at $p < 0.05$ suggests that the demand for river recreation decreases with increase in group size. This result seems intuitive because travel

planning of large party is a joint decision of multiple people that may face different travel constraints such as money, time. Even though some of the non-motorized travel trip such as rafting may be preferred in a group, a larger group would likely to take fewer trips. The negative effect of party size on trip demand has been reported in other recreation studies (Cho et al., 2014; Dorison, 2012; Sardana et al., 2016). Sardana et al. (2016) suggested that smaller groups tend to visit the national forests more often than larger groups for outdoor recreation. The coefficient of a number of people under sixteen years of age (*UNDER16*) was negative but not significant across the models, indicating that having children during the recreation trip would not affect the trip demand. This result is in line with Cho et al. (2014) who also found no difference in national park visits between travelling groups with and without children.

3.4.3 Designation variables

The estimated coefficient on designation (*DESIGNATED*)⁵ was positive but not significant in either of the models suggesting that there is no difference on demand for non-motorized boating between designated and non-designated rivers. This result is consistent with results from previous river recreation studies (Keith et al., 2008; Moore and Siderelis, 2002; Moore and Siderelis, 2003; Palmer, 1993; Walsh, Sanders, and Loomis, 1985) although none of

⁵ The demand models without the slope interaction of designation (*TCDESIGNATED*) were also estimated but there was no difference on the demand between designated and non-designated rivers across models of alternative cost of time assumptions.

them had investigated this issue using national level data. There could be many reasons for this observation. Firstly, the designation does not directly restrict or affect public access to rivers for recreation. Secondly, there is limited accessibility to some WSR, in particular to Wild and Scenic categories and boaters could prefer sites where they can easily access. Thirdly, recreationists might be unaware of the designation and scope of value such rivers. This was the case in the study in Farmington River (Moore & Siderelis, 2002) where more than half of the respondents were unaware that the river was designated even though most of them felt designation is important for the river protection. Similarly, the distance can also play an important role as Weiler (2006) mentioned that long-distance travelers are more sensitive to designation signal than those who live closer to recreation sites. In this study, only 30% of the recreationists stayed overnight, suggesting that the majority live relatively close to the rivers and therefore, are likely to be less affected by designation signals. In contrast, Moore and Siderelis (2003) found that most of the users were aware of designation status in Chattooga, but that might be due to Chattooga River being one of the popular rafting destinations with the large participation rate in the southern United States. Finally, WSR designation is not similar to the Wilderness Act which is considered the highest level of conservation protection for federal land, and Loomis (1999) showed an increase in visitation when new wilderness area is added. The WSR designation was to maintain the free-flowing condition of the river and to protect the rivers from adverse development such as dams or water development projects are constructed on designated rivers. Therefore, enhancement of scenic values and water quality could affect recreational use whereas the quality of non-designated river may be degraded due to lack of legal obligation. This could

be positively related with visitation, but the effect of these factors is smaller or insignificant compared to other factors that impact non-motorized boating demand.

The coefficient of the interaction of designation dummy and travel cost (*TCDESIGNATED*) was found to be negative but not significant; suggesting that price response and net economic benefits⁶ were not different between designated and non-designated rivers. Therefore, this result could not reject the hypothesis that there is no difference in CS from visiting designated and non-designated rivers for non-motorized boating. While calculating the per trip CS value of designated river by following the equation (3.10), the CS from the designated river was found lower than from non-designated river. However, estimated coefficients of the interaction term in the models were not significant. Despite more than two dozen studies on the economic value of non-motorized boating, only Bowker et al. (1997) examined the price response of designation and the corresponding economic value, but their study was limited to only five rivers including two designated rivers. The authors found that designation was positively related to price response, resulting in higher economic value from designated than a non-designated river. However, their findings cannot be generalized because of

⁶ Following Hesseln, Loomis, and Gonzalez-Caban (2004), the estimated coefficients of travel cost and the interaction of travel cost and designation dummy from Equation (8) can be used to calculate the CS from designated river. Equation for CS from designated rivers is given by Equation (10).

$$CS_{Designated} = - \left(\frac{1}{\beta_{TC} + \beta_{Designated}} \right) \quad (3.10)$$

the small sample size (only five rivers), and they did not test the effect of designation on the recreational demand since their objective was to assess the effect on price interaction only. Although there were similar characteristics among those rivers such as floating length and time, the difficulty of rapid, and length of the season, but dam control was not present in the designated rivers while continuous flow was controlled by a dam in three non-designated rivers. Therefore, dam control which is one of the objectives of the WSR act could be one of the factors in having higher net economic benefit as free-flowing water ensures uninterrupted recreational opportunities for boaters. Similarly, Walsh et al. (1985) found the positive economic value of designation by comparing users' willingness to pay for designation with a proposed cost of designation in 11 rivers in Colorado.

3.4.4 Variables related to the site and river characteristics

Among the site characteristics, the estimated coefficient on the number of camping sites at river exit (CAMPSIZE) was found to be negative and significant at $p < 0.05$, suggesting that trip demand is likely to decrease with increases in nearby camp size. About 70% of the respondents were one-day recreationists which mean most did not camp or stay overnight during the trip. The number of campsites could affect crowding, cleanliness, safety, and ease of facility use at the site. Therefore, larger campsites could be less appealing to the recreationists. Since Deyak and Smith (1978) found that congestion at the recreation site affects recreation participation, increases in the number of campsites result in congestion, which in turn could affect the demand for non-motorized boating. Boaters' perception of safety and satisfaction both may decline when they encounter more people around (Tseng et al., 2009). The positive and

significant coefficient on the availability of boat ramp or launching access at take-out point (*RAMP*) at $p < 0.1$ suggests that the demand for non-motorized boating is higher in the river sites where the boat ramp is available at take-out point. This is consistent with previous studies including Parsons et al. (1999), who found a positive effect of a number of ramps at the fishing sites on fishing demand at reservoirs in Tennessee. Similarly, Murdock (2006) found that availability of ramp positively affects participation in fishing while Timmins and Murdock (2007) found that availability of paved boating launch increased fishermen's utility in Wisconsin.

Among the river characteristics variables, the coefficient on the lake (*LAKE*) was negative and significant at $p < 0.05$ across the model, indicating that demand for non-motorized boating decreases in rivers that have a lake nearby. Non-motorized boating generally requires kinetic energy from the moving water which is only available on sloped lands. In addition, the NVUM survey does not differentiate the type of non-motorized boating activities and preferred level of speed varies among different type of activities. The coefficient on river rapid class dummy (*RAPID4*) was positive and significant at $p < 0.05$, suggesting that demand for non-motorized boating in a river with at least one rapid class of IV or higher has higher demand compared to the river with lower rapid classes. This result is intuitive because trip demand is likely to increase with increases in an adventure from higher class rapids. The higher level rapids are typically associated with better river quality for non-motorized boating (Bowker et al., 1996), and they are also one of the most important reasons for boating visits (Shelby, Johnson, &

Brunson, 1990). In addition, Bowker et al. (1996) found that CS from rafting in a river with higher rapids was found to be as high as 49% in comparison to rivers with lower rapid class.

The estimated coefficient on discharge (*DISCHARGE*) was found insignificant although other studies have found a positive relationship (Amirfathi et al. 1985; Boyles et al., 1993; Loomis & McTernan, 2014; Siderelis and Moore, 2006; Ward, 1987). It is expected that increases in water flow improve the overall experience which would increase the number of trips and benefits per trip. Loomis and McTernan (2014) found that kayaker and rafter willingness to pay increases with increases in flows. More specifically, their demand increases from 1.63 trips at 300 cubic feet per second to 14 trips per season when the flows at 1900 cubic feet per second. Similarly, Boyer et al. (2017) found a positive relationship between water levels and visitation of boaters and fishermen at a reservoir in Oklahoma. The quadratic effect of water level (the positive and negative sign on water level and water level squared respectively) suggested that water level increases trip demand but at a decreasing rate. The coefficient on velocity (*VELOCITY*) was negative and significant at $p < 0.1$, suggesting those visiting rivers of higher velocity were likely to make fewer trips than visitors to rivers with lower velocity. The higher water speed is combined with higher rapid class adds excitement level of recreationists. It was unclear from NVUM data about the type of non-motorized boating activities. Some of the activities such as rafting, canoeing is suitable to high water speed is combined with higher rapid class for better recreational experience while activities such as boating, sailing, and even tubing are more suitable in moderate or low-velocity rivers. The recreational trip with children and family may prefer a gentler, smoother ride than more adventurous experience. Magirl et al.

(2009) found that a shoreline-based water survey misrepresents the water measures along the centerline of a rapid. Since the water velocity from USGS was not collected at the rapids where water velocity is likely to be higher than near shoreline, the data might not represent the actual water velocity recreationists have felt during the trip.

3.4.5 Other variables

The negative and significant coefficient on a number of days spent during the current trip on non-motorized boating (*DAYS*) at $p < 0.05$ was consistent with previous studies (Bhat, 2002; Bell & Leeworthy, 1990; Creel & Loomis, 1990; Melstrom, 2014; Shrestha et al., 2002). The result suggests that the demand for non-motorized boating trips is lower for those who spend more time during the trip. It is possible that long duration trippers face more travel cost, or restricted to working schedule that allows them to take fewer trips. This is opposite to Bowker et al. (1997) and Bowker et al. (1996), who found that river rafters who spend more time on site tend to visit the river more often. Other recreational studies also found a negative relationship between time on site and the demand for the recreation (Acharya et al. 2003; Martínez-Espiñeira & Amoako-Tuffour, 2008). The effect of the recession and its aftermath (*RECESSION*) was found negative and statistically insignificant across the models, suggesting the demand for non-motorized boating during the recession was not different than before or after the recession. While there is no precedent literature on the effect of a recession on river travel demand, Loomis and Keske (2012) found that the recession does not affect total expenditures or the number of visits in trail-based outdoor recreation activities. In contrast, a time series analysis of annual visitation at national parks and indicators of economic growth by Poudyal, Paudel, and Tarrant (2013)

found that the national park system experienced significantly lower visitation during years of economic downturn. A recession could affect river recreation visits in two ways: a participation decision (visits or not) and a participation intensity decision (how often). Therefore, individuals who are not directly impacted by recession remain in the on-site sample and visit the rivers as similar to a non-recessionary period, while individuals who are directly impacted with job loss or salary reductions drop out of the sample and therefore, have no effect on the average number of participant trips. The coefficient on Round 3 dummy (*ROUND3*) was found positive and statistically significant at $p < 0.1$ across the models, suggesting that the non-motorized boating demand was significantly different between NVUM's data collection cycle. This result is different from Cho et al. (2015) who found no difference in national forest visits between two NVUM survey periods (Round 1 and 2).

3.4.6 Economic welfare estimates

The economic benefit of non-motorized boating trips was derived by combining the estimated travel cost coefficients in Table 3.2 with the equation presented in equation (3.8). Then, the CS value per trip was divided by the mean number of people in the traveling group (*PEOPVEH*= 2.98) to obtain CS per person per trip. With no opportunity cost of time assumed, the estimated per person per trip CS was \$66. Following Kling and Sexton (1990) and Martínez-Espíñeira and Amoako-Tuffour (2008), the lower and upper bounds of the confidence interval of the price coefficient were calculated through bootstrapping the standard errors. Therefore, the corresponding 95% confidence interval of CS per person through bootstrapping was \$51 and \$92. When the wage rate was assumed, the estimated per person per trip CS was \$87 with 95%

confidence interval of \$63 and \$139. CS values for designated rivers were not reported in this paper because the coefficient of interaction between travel cost and designation dummy (*TCOST* * *DESIGNATED*) was not significant in either model. The values of net economic benefits of non-motorized boating from this study can still be compared with previous welfare estimates because findings of this study were based on national level data and fall within the range of estimates reported in previous studies. For instance, a recently published benefit transfer study by Rosenberger et al. (2017) found estimated per person per day CS of \$117 for non-motorized boating activities based on data from 23 studies. The travel cost literature showed variation in benefits because the economic value is defined by many factors including type of non-motorized boating activities, river characteristics, recreational site characteristics, along with methodologies and assumptions used in the studies.

Only two studies have used national level river recreation data to estimate economic value in the United States (Bergstrom & Cordell 1991; Bowker et al., 2009). Bowker et al. (2009) estimated per person per trip CS of \$118 and \$194 when zero opportunity cost and 33% of wage rate is assumed in the TC variable, respectively. However, the authors estimated the economic value of aggregated data for biking, horseback riding, and non-motorized boating in national forests using NVUM's Round 1 data (January 2000 to September 2003). Bergstrom and Cordell (1991) used Public Area Recreation Visitors Study (PARVS) data from 200 sites including national forests, national parks, and state recreational sites and employed a multi-community, multi-size zonal TC model to develop demand equations and estimate the net economic. They estimated per trip per person CS for different non-motorized boating separately:

rafting/tubing (\$67), canoeing/kayaking (\$45), and rowing/ other boating (\$92). Previously, Rosenberger (2016) reported CS values as high as \$512 per person per day (Middle Fork of the Salmon River, a designated river in Idaho) and lows of \$5 per person per day (Salk River, Arizona), along with mean value across the estimates of \$129 per person per day (for instance, \$118 from Glen Canyon dam releases and downstream, Arizona). A recent TC study that assumed one-third of the wage rate as the opportunity cost of time found a CS per person per day trip of \$115 for non-commercial whitewater kayakers (Loomis and McTernan 2014). Based on survey data from the Poudre River, a wild and scenic river in Colorado, they estimated kayakers' willingness to pay at \$100 at mean flows. Similarly, Bowker et al. (1996) examined per trip CS associated with guided whitewater rafting and found the values between \$198 and \$301 for the Chattooga Wild and Scenic River and the values between \$147 and \$206 on the Nantahala River on the zero and 25% of wage rate as the opportunity cost of time, respectively. Compared to Bowker et al. (1997), the estimates from this study are lower, partly because their estimates are for guided rafting in five rivers instead of aggregate values for all type of non-motorized boating in rivers across all national forests. Siderelis and Moore (2006) estimated per person per trip CS of \$204 and \$155 for guided rafting and self-guided kayaking in the Chattooga River, respectively. Using benefit transfer approach of 20 studies, Kaval and Loomis (2003) found CS per person per day of \$132 for boating, rafting, and canoeing which is within the range of this study. A list of previous studies on river recreation, their welfare estimation, area, method employed type of recreation activities; designation status is presented in Appendix B.

The per person per trip CS value of the estimate and NVUM annual visits estimation of non-motorized travel activities for 2015 were used to derive the total annual economic benefits of non-motorizing boating access to rivers in National Forest System. Among 149 million annual visitors in the national forests, only 1.64 million primarily visit the national forests for non-motorized boating (USDA Forest Service, 2015). Therefore, nationwide net economic benefit of non-motorized boating was found to be \$108.24 (with no opportunity cost of time assumed) and \$142.68 million (with one-third of wage rate assumed as the opportunity cost of time). Bergstrom and Cordell (1991) is the only study reporting the total nationwide CS values, but their estimation cannot be compared directly with results of this study because they estimated the economic value for the rivers all over the country instead of national forests. They estimated annual net economic benefits for different non-motorized boating separately: rafting/tubing (\$597.90 million), canoeing/kayaking (\$1,794.32 million), rowing/other boating (\$5,693.48 million).

3.5 Conclusion

This study assessed and compared the demand for and value of non-motorized boating access between the Wild and Scenic Rivers designated and non-designated rivers. Findings from this study have several implications. First, the economic benefit from accessing the national forests for non-motorized boating trips per person was estimated to be between \$66 and \$87. Nationwide, the economic benefits were as high as \$142.7 million, indicating that the non-motorized boating activities on national forests can generate considerable economic benefits for the public. Second, the findings suggest the WSR designation does not signal different demand

for and economic value of non-motorized boating access. Contrary to a common belief that designation would increase the recreational demand, our results imply that designation does not significantly increase visitation or economic value. Third, river and site characteristics such as ramp availability, camp size, rapid class difficulty level, and flow velocity are significantly related to the demand for non-motorized boating.

The uniqueness of this study lies in multiple aspects, including deriving estimates using a rich dataset that covered multiple years and hundreds of river sites across the nation, and scientifically comparing the designated and non-designated rivers. In addition, the generality of this result is higher than previous studies because this study used more robust econometric modeling, more precise measurement of travel cost using recreation fees and various wage rate assumptions, and many river and site characteristics in the demand model that were missing in previous studies. The findings enhance our understanding of the net benefit of non-motorized boating. Such information will be helpful to management agencies such as the USFS as the national estimates demonstrate that non-motorized boating on public lands, particularly on national forests, is substantial. The findings will also be useful for resource managers and planners to compare benefits with the cost of maintaining non-motorized boating opportunities in the public lands. Similarly, these estimates could be used by land managers and policy makers to draw the economic value of non-motorized boating or similar recreation activities of alternative sites within the nation through benefit transfer approach.

The results related to potential difference on the demand and economic value of non-motorized boating between designated and non-designated river should be of interest to resource

managers and planners. It suggests that WSR designation does not affect recreational visitation as it does for other public designations such as wilderness or national parks. Considering the 50th anniversary of WSRA and looking ahead, the results could help to inform decisions on balancing recreational demand along with protecting river values and maintaining water quality. One reason for no difference in demand for non-motorized boating between designated and non-designated river could be imperfect information about the designation, and therefore, information on recreation values and use of the site should be appropriately disseminated to recreationists.

Among three WSR categories, Wild and Scenic areas are primitive and mostly inaccessible by roads and these areas could be favored by recreationists who enjoy a pristine environment and wilderness. Therefore, if managers and planners are interested in increasing visitation, future planning should focus on promoting activities such as camping, hiking, fishing, scenic viewing instead of non-motorized boating. River managers should carefully develop the river sites to increase visitation because the different site and river factors have contradictory impact on demand. For instance, the availability of ramps is positively related to demand whereas the numbers of camping sites decrease the demand. Therefore, boating sites should have boat launch or ramp for easy access to the river and camping sites should be established far from the river to avoid congestion. In addition, natural river factors such as water velocity and level of rapids should be taken into account when establishing access points.

Despite using national-level data and analyzing more than half of the designated rivers, this study has some limitations. Only demand and economic values between designated and non-designated river were considered, without including all the other factors affecting visitation. If

possible, future investigations should compare the demand for the status quo condition and again after the designation. Another approach could be to analyze a panel dataset from multiple designated rivers over time so that changes in the demand, if any, could be observed in the long run. In addition, it would be interesting to analyze if the recreation value of different categories of WSR designation differs among the three categories. The aggregate and disaggregate value of designated river would be helpful to evaluate the overall effect and specific designation categories and to plan management strategies for specific categories.

A few caveats of this study, mainly due to theoretical limitations of TCM and the nature of dataset, should be noted. The estimated CS values are conservative because long-distance travelers and respondents beyond the conterminous United States were not considered in the analysis because those visits were likely to be multi-destination and multipurpose trips. Future research with broader scale data is needed to validate the results because the findings of this study are only based on national forests. Only one-third of the NVUM survey collects income and recreational fees, and missing values of recreational fees were replaced by average values of the particular site. Moreover, reported recreational fees were used while computing travel cost variable and variation in the fees such as discounts, and changes over the season was not considered. The multiple sources were used for site and river-related data as NVUM survey does not collect those information and different sources have different standards to assign the values of the site or river measurements. Further, other important variables such as length of travel, floating duration, previous experience, and dam control which could potentially affect the visitation could not be included due to lack of data.

CHAPTER 4

ESTIMATING THE VALUE OF ELK HUNTING ACCESS USING

PERMIT APPLICATION DATA

Abstract

The Tennessee Wildlife Resource Agency (TWRA) started elk restoration in the five-county region surrounding the North Cumberland Wildlife Management Area (NCWMA) in 2000. To manage the growing population, a quota hunting program was initiated in 2009. While the restoration program is well justified from an ecological benefit perspective, continuous public support for the program requires an understanding of the economic benefits of this program including hunting. Available estimates of the benefits of elk hunting are based on studies conducted almost two decades ago, and were from western states where agencies issue a substantially higher number of elk permits than in Tennessee. The objective of this study was to develop a model of demand for elk permits and estimate the value of the opportunity of receiving an elk hunting permit in Tennessee. Since a typical trip-based individual travel cost model is not feasible in lottery-rationed hunting permit system, this study employed a zonal travel cost method (ZTCM) to model the demand for elk hunting permits, in which permit applications by zip codes were analyzed along with travel cost, and the demographics of each zip code using different regression models. The estimated consumer surplus, a monetary measure of the expected benefit or the value of the opportunity of receiving an elk permit was estimated and then aggregated across zip codes to derive the total benefit of elk hunting in Tennessee. The estimated consumer surplus under different modeling assumptions suggests a substantial value for elk hunting in Tennessee. The net economic benefit of the opportunity of receiving a permit per person was estimated to be in the range of \$181 to \$352 depending on the modeling assumptions, and the total benefit of elk hunting opportunity was found to be as high as \$3.44

million. The findings can inform researchers, recreation managers, and policy makers in understanding the net benefit of hunting opportunities generated as a result of elk restoration in Tennessee and similar regions where elk restoration is being considered.

4.1 Introduction

Big game hunting is a popular outdoor recreation activity in the United States with 11.5 million adults (5% of the total population 16 years and older) annually hunting big game animals such as elk, deer, and wild turkey (U.S. Fish & Wildlife Service, 2016). Elk hunting is particularly popular in a few states in the Northwest and northern Rocky Mountains (Aiken, 2016). While most of the elk population is distributed in the western part of the country, at least ten elk restoration projects have been operating in the eastern region (The Rocky Mountain Elk Foundation, 2018). With increasing success of the restoration programs, state agencies in some states including Kentucky, Arkansas, and Tennessee have recently established elk hunting programs.

Recreational benefits of outdoor resources such as access for elk hunting typically include non-market goods and are usually difficult to quantify. Management decisions about natural resources based recreation may not be optimal without proper valuation and accounting of all uses of such resources (Loomis & McTernan, 2014). The net economic benefit, also called consumer surplus (CS), is the measure of net benefit recreationists derive from accessing a site (i.e. wildlife management area) for recreation use (i.e. elk hunting), and the net benefit derived

by individual recreationists can be summed across the user population to derive the total benefit of recreational access to the site.

Since the start of the restoration program in 2000, the elk population has been growing with the population estimated at 349 in 2016 (TWRA, 2018). The gradual expansion of the elk population could bring positive (e.g. hunting, elk viewing) as well as negative impacts (e.g. crop damage, highway collision) in rural communities. In this context, state wildlife agencies and conservation organizations are interested in characterizing the economic benefit or the public value of restoration programs through new hunting opportunities. The continued public support for management of elk population in the region may also require an understanding of the benefits the elk program brings to the region through outdoor recreation including hunting. While the existing literature on the economic valuation of elk hunting is focused on the western states, those estimates may not be applicable to eastern states with limited elk hunting opportunities. The estimated benefits of elk hunting from this study may help them weigh in between expected benefits and costs of restoration.

Using the case of the recently established quota hunting program in the North Cumberland Wildlife Management Area (NCWMA) in Tennessee, this study estimated the economic value of the opportunity of receiving a permit for elk hunting. Although this study followed similar theoretical framework developed by Scrogin et al. (2000), the only study valuing lottery-rationed elk hunting permit, elk hunting in Tennessee is unique in many ways. The number of lotteries in New Mexico examined by Scrogin et al. (2000) was 215 compared to a single lottery in Tennessee. Elk hunting permits have been issued for a longer period of time in

New Mexico compared to a new practice in Tennessee (since 2009), and the number of hunts and elk population was much larger in New Mexico. The information about the number of permit applicants in the past year is available to the New Mexico hunters in the permit application whereas hunters do not have any information about their chance of winning the lottery in Tennessee. In addition to providing updated value after two decades, this is the first study of elk hunting valuation in the east of the Rocky Mountain region.

Contingent valuation (CV) and travel cost methods (TCM) are commonly used stated (based on data individual's response to hypothetical questions) and revealed (based on individual's actual behavior data) preference methods, respectively to value the non-market benefits of recreation access. In particular, TCM is the most commonly used method for valuing access to recreational sites (Parsons, 2003). The TCM approach typically starts with developing a model for trip demand as a function of travel cost and other covariates and exploits the relationship between trip frequency (i.e. quantity) and travel cost (i.e. price) to characterize the marginal benefit of recreation trips, also known as CS derived by an individual recreationist. Estimating the value of the opportunity to hunt with a trip-based travel cost model in places like Tennessee presents a unique challenge because elk hunting permits are regulated through a lottery-rationed program.

4.2 Previous studies on the economic value of elk hunting

Numerous studies have studied the economic value of elk in the western United States where the population of elk and number of hunting permits are larger (Aiken, 2016; Aiken 2009;

Bolon 1994; Cory & Martin, 1985; Duffield 1988; Loomis et al., 1988; Park et al., 1991; Sort & Nelson, 1986; Scrogin, 2000). Although lottery-rationed recreation is common in the United States (Scrogin & Berrens, 2003) and has been studied in the past (Boyce, 1994; Buschena et al, 200; Loomis et al., 1982; Nickerson, 1990; Reeling et al., 2016); only Scrogin et al. (2000) attempted to value elk hunting in a lottery-rationed demand model framework.

Within the big game hunting literature, various valuation approaches have been used to estimate demand and to conduct welfare analyses of elk hunting including CV (Aiken 2016; Brookshire et al., 1980; Cory & Martin, 1985; Fried et al., 1995; Loomis et al., 1991; Loomis et al. 1988; Park, Loomis, & Creel, 1991; Sorg & Nelson, 1986), TCM (Duffield 1988; Sorg & Nelson 1986; Scrogin, 2000), benefit transfer (Bolon et al., 1994; Rosenberger & Loomis, 2005), and hedonic regression analysis (Buschena, Anderson, & Leonard, 2001). A review of recreation valuation studies by Rosenberger (2016) found that elk hunting studies mainly used either TCM or CV method. Among the CV studies, some assessed hunter willingness to pay for the opportunity to hunt elk on an existing scenario (Aiken, 2006, 2009; Bolon et al. 1994; Boyle, Roach, & Waddington, 1998; Brookshire, Randall, & Stoll, 1980). For example, Aiken (2016) used national level recreation survey data from the U.S. Fish and Wildlife Service to estimate net willingness to pay for wildlife-based recreation activities. In particular, data for elk hunting from five states (Colorado, Idaho, Montana, Oregon, Wyoming) was used, and the mean net economic value was estimated to be \$109 (all CS estimates reported on this paper in 2018 dollars) with the median being \$102. His estimates were based on the reported expenditures on several items during elk hunting trips including gasoline, transportation, food, and lodging.

A number of studies have analyzed the economic value of elk hunting in alternative scenarios of policy change or resource condition improvement. For example, Scrogin et al. (2000) estimated and compared the net benefit of elk hunting opportunity and associated license revenue before and after a change in hunting regulation to increase the chance of resident hunters being selected in the permit lottery. Loomis et al. (1988) compared the net benefit of an elk hunting trip in Montana among hunter groups employing a CV survey. They found that the hunters in Montana were willing to pay \$595 per trip (\$90/day) in current elk hunting conditions, but were willing to pay as high as \$780 per trip (\$123/day) if the chance of harvesting an elk was doubled. They also found different WTP among hunter groups with trophy hunters willing to pay \$814 per trip while non-trophy hunters were willing to pay only \$380. Sorg and Nelson (1986) used both the TCM and CV methods to estimate the net economic value of elk hunting among Idaho hunters. In the CV survey, respondents were asked to indicate their WTP for elk hunting trip in two scenarios: under the existing elk hunting conditions in 1982 and 1983, and an alternative condition where the sighting of elk would be doubled. The estimated CS was found to be \$117 and \$209 for current condition per trip respectively for the year 1982 and 1983, and \$338 per trip for doubling the number of elk seen in year 1983. A similar study by Park et al. (1991) in Montana conducted a dichotomous CVM survey of big game hunters asking their WTP for different hunting conditions (current condition, doubling the chance of elk harvest, reducing crowding condition). They found the value of elk hunting in the range of \$227- \$330 under different site conditions for hunting. Fried et al. (1995) conducted a CV survey of hunters in eastern Oregon using a various bid values between \$82 and \$825. Mean WTP estimated for a condition that guaranteed successful hunting of an elk was \$473 with a median value of \$148.

Few studies have employed TCM in elk hunting valuation. John Duffield (1988) employed a zonal TCM model using a telephone survey of Montana elk hunters and found a net economic value of \$396 per trip (\$141 per day). The annual aggregate value of Montana elk hunting was \$89.3 million which was calculated by multiplying the value per time with 572,000 hunting days. A similar study in Idaho by Sorg and Nelson (1986) found the economic values of \$145 and \$229, depending on the modeling assumptions.

Within studies estimating the economic value of elk hunting using TCM, only Scrogin et al. (2000) studied a lottery rationed allocation of permits. As most of the elk hunting valuation studies were conducted in the 1980s and 1990s, elk hunting permits might not have been rationed by lottery due to the abundance of elk population or lack of regulation on elk hunting to maintain an adequate population. Scrogin et al. (2000) is the most recent study which analyzed the economic value of the opportunity of receiving an elk hunting permit relative to a policy change that ensured at least 78% of the lottery licenses distributed to resident hunters. Using the elk hunting lottery application data for two years in New Mexico, they found that resident hunters enjoyed an increased net benefit as a result of the policy change. Due to the changes in the policy, CS for 215 hunting permits in the entire New Mexico was as high as \$6.18 million. The net economic benefits of elk hunting as reported in previous studies are provided in Appendix C.

Beside CV and TCM, past studies have also used hedonic regression analysis and benefits transfer method. In a recent database of 421 recreational use value studies, Rosenberger (2016) reported 39 estimates from 12 studies of elk hunting from 1977 to 2009. He reported variations in the CS estimates among the studies as the value of elk hunting depends on many

factors including study methodologies, assumptions, sampling methods, the location of hunts, and abundance of available permits. Buschena et al. (2001) studied elk hunting in Colorado where hunting permits are distributed through a modified lottery in which applicants can accumulate preference points, increasing their chances of gaining a permit. By using a hedonic regression method, they estimated the marginal value of an elk permit based on the opportunity cost involved in accumulating enough preference points to acquire an elk permit and estimated the impact of hunt characteristics on the permit value. Estimated marginal willingness to pay for resident and non-resident hunters was approximately \$65 and \$435, respectively.

4.3 Elk hunting in Tennessee

Historically, elk were present in Tennessee with last known record of an elk being sighted was in 1865 (TWRA, 2018). Overharvesting and habitat destruction gradually led to the extinction of elk population in the southeastern United States (O’Gara & Dundas, 2002). TWRA decided to restore elk in Tennessee in the late 1990s. One of the goals of the elk restoration project was to develop an elk herd capable of providing wildlife viewing opportunities and sustainable hunting (TWRA, 2018).

The translocation began in December 2000 from Elk Island National Park, Canada to the North Cumberland Wildlife Management Area (TWRA, 2018) with the assistance of many agencies including the Rocky Mountain Elk Foundation, Tennessee Wildlife Federation, Campbell Outdoor Recreation Association, U.S. Forest Service, Parks Canada, Canadian Food Inspection Agency, Safari Club International, Tennessee Valley Chapter of Safari Club

International, Shikar Safar International, University of Tennessee Department of Forestry, Wildlife and Fisheries, and the University of Tennessee College of Veterinary Medicine (TWRA, 2018). The elk restoration area consists of 670,000 acres of land located in Scott, Morgan, Campbell, Anderson, and Claiborne counties with the center of the restoration zone being the Royal Blue Wildlife Management Area. Although the original plan was to release 400 elk in the area, only 201 elk were released by 2008, when it was suspended due to the spread of Chronic Wasting Disease (CWD). The biologists believe that the area could sustain up to 2000 elk, but the latest estimated elk population was 349 in 2016 (TWRA, 2018).

The elk hunting permit in Tennessee has characteristics similar to other big game hunting permits (Nickerson, 1990) such as boundary, weapon, and season/time restrictions, as well as bag limits. Since the TWRA started hunting in 2009, the number of permits issued has gradually increased. The number of hunting permits available were six (four drawn gun permits, one auction gun permit, and one drawn youth permit) in 2015, 11 (four drawn gun permits, one auction gun permit, one drawn youth permit, five drawn archery permits) in 2016, and 15 (six drawn gun permit, one auction gun permit, one drawn youth permit, seven drawn archery permits) in 2017. The highest bidder on eBay was given an auction permit and the bidding receipts were donated to a non-government organization with fund-raising proceeds designated to the TWRA elk program.

The hunting application can be submitted through an online application, at TWRA regional offices, or at TWRA licensed agent locations. The successful applicant will not be allowed to apply for ten years following a successful draw. The bag limit is one antlered elk per

permit and hunting on other public lands outside of WMA (e.g. state parks) is prohibited. The hunters have to obtain verbal or written permission from landowners if they want to hunt in private lands around the NCWMA. Although the permit lottery is random, non-resident applicants were restricted to no more than 25 percent of the drawn permits.

4.4 Travel cost method for economic valuation

TCM is one of the commonly used revealed preference valuation method to estimate the net economic value of recreation access (Haab & McConnell, 2002; Parsons, 2003). It is a demand based model for recreational use of a site or multiple sites (Parsons, 2003) where the number of trips taken by an individual is modeled as a function of the cost of accessing the site and other social and demographic characteristics of the recreationist. The welfare measure or the net benefit a recreationist derives by accessing the site is generally expressed in terms of net economic benefit or CS, in other words, it is the difference between how much an individual is willing to pay and the actual cost she or he actually incurs in accessing the site (Freeman, Herriges, Kling, 2014).

Several assumptions must be addressed within the data for the valuation measures from TCM to be considered valid (Haab & McConnell, 2003). The travel and time cost to a site is a proxy for the price of a recreational trip and the cost of travel must be incurred for a single destination trip for the sole purpose of recreation. In addition, travel time is neutral suggesting no utility or disutility from the travel time.

In travel cost modeling, the empirical process of estimating net economic benefits involves two steps in estimating the parameters of the demand function and the calculation of the welfare measure from the estimated parameters (Haab & McConnell 2002, p. 159). Following Freeman (1993, p. 443-447), the travel cost is based on actual behavior reflecting utility maximization subject to constraints. As Haab and McConnell (2002, p. 144) suggested, the utility maximization equation subject to the constraints can lead to the general demand function:

$$Y = f(P, H, Q) \quad (4.1)$$

where Y is the number of trips demanded, P is the cost associated with travel to the recreation site, H is a vector of individual's socio-economic demographic factors, and Q is a vector of site characteristics.

When Clawson and Knetsch (1966) first proposed the travel cost model, it was a zonal model with the dependent variable being trips per capita. Since then, the individual TCM has been developed with the dependent variable being a number of trips because it allows modeling individual demand, ensures higher statistical efficiency, and avoids the arbitrary nature of zonal definition in the zonal model. On the other hand, the individual travel cost method (ITCM) based on on-site survey has its own problem of truncation (excluding non-visitors) and endogenous stratification (oversampling frequent visitors) resulting in biased estimation if these issues are not addressed because the sample is not the representative of the population (Grossmann, 2011). Using Monte-Carlo simulations in a simulated population's demand for trips to parks, Hellerstein (1995) compared the bias from ITCM (model misspecification) and ZTCM (aggregation) and

found that the latter often outperforms the former, particularly, when average per capita demand is small and variance across the individual is small.

The underlying assumption in ZTCM is that that behavior of individuals within a zone is identical (Haab McConnel, 2002), but aggregating the individual observation by zone averages out some of the information available at the individual level (Brown & Nawas, 1973). The use of such aggregate data instead of individual data results in aggregation bias (Moeltner, 2003) because aggregation do not systematically account for the heterogeneity in individuals level and the parameter estimates does not represent individual behavior (Grossmann, 2011). A commonly used approach is to estimate per capita demand function in zonal travel cost (Grossmann, 2011; Loomis et al., 2009). Using the individual zone as a unit, ZTCM estimates the average demand function across the zones and demand from each zone is determined by travel cost and the opportunity cost of time between the zone and the recreation site and the demographics of the zone including income, population, and age. The zonal TCM is useful in certain situations such as where visitor data is available from secondary sources, each visitor can take only one trip per year, or data is available only for the most recent trip (Loomis et al., 2009). In addition, the zonal model does not require correction for truncation and endogenous stratification because information for non-visitors data can be accessed from the secondary data sources (Grossmann, 2011). Since the permit application data was available from the secondary source, ZTCM was used in this study.

4.5 Empirical models

Wildlife managers use permits to regulate access to recreation opportunities such as hunting to guarantee equity of access and to regulate the excess demand in comparison to limited supply (Reeling et al., 2016). The random lottery is one of the commonly used methods to allocate limited supply among potential hunters (Scrogin et al., 2000). The demand for such hunting opportunities where rationing regulates the demand is high because the price of the permits are typically priced at rates below than it would have been exist in the normal market.

Instead of applying traditional ZTCM where demand per capita is estimated using the number of applications per capita as a dependent variable, and travel cost and travel time along with socio-economic variable as independent variables, the modified zonal travel cost model by Loomis (1982) was used as the first model for the data analysis. The TCM with adjustment for lottery-rationed permit by Scrogin et al. (2000) was used as the second model to address the difficulty in estimating demand and benefits.

4.5.1 Modified ZTCM

Loomis (1992) and Dwyer, Kelly, and Bowes (1977) stated that the recreation site should have sufficient capacity to accommodate all the demand to visit a recreation site and travel cost and recreation use measured do not show the actual recreation benefit if this condition does not hold. Because the benefits from the recreationists repealed in the lottery (those who were not selected) are not included in benefit estimation and the demand curve only represents the demand and benefits of successful lottery applicants, applications for the recreation rather than actual trip

should be used to satisfy the assumption that observations of site use reflect unconstrained demand (Loomis, 1992). In addition, using the applications improves the per capita demand estimation because the inverse relationship between a number of trips per capita and travel cost does not appear due to the randomness of the lottery especially when the number drawn is very small.

The standard practice in the ZTCM literature is to use visitation rate per zone, i.e., visitation per capita by zone. In one of the early travel cost studies on big game hunting, Loomis (1982) modified the standard ZTCM to estimate the economic value of elk hunting under a lottery-rationed system using the number of applications per capita (person) as the dependent variable. He then compared the modification of a standard TCM with the number of visits per capita as a dependent variable, and travel cost and travel time as independent variables. The modified model showed improvement in demand curve and benefits estimation compared to standard ZTCM. Based on the theoretical foundation of demand function in equation (4.1) and following Loomis (1982), the empirical zonal travel cost model for lottery rationed elk hunting was specified as follows:

$$\begin{aligned} & APPLICATIONS_i / CAPITA_i \\ & = TC_i + INC_i + INCSQR_i + HUNTERN_i + AGE_i + AGESQR_i + \mu_i \quad (4.2) \end{aligned}$$

Where $APPLICATION_i$ represents the number of applications applied from zip code i for elk permit to hunt elk in NCWMA for year j , TC_i is the cost required from zip code i to reach the NCWMA, INC_i is the average household income of the zip code i , $INCSQR_i$ is the quadratic for

variable INC_i , $HUNTERN_i$ is the average number of big game hunters of the zip code i , AGE_i is the average age of applicants from zip code i , $AGESQR_i$ is the quadratic term for variable AGE_i , and the term μ_i is random error.

Loomis et al. (2009) suggested using the natural log transformation of the dependent variable in ZTCM. The reasons for using transformed dependent variable are: semi-log function is similar to functional form of commonly used Poisson and negative binomial count data model, the distribution of transformed dependent variable is close to normal, it also allows nonlinearity in the demand function, and the transformation also makes calculation of CS easier (Loomis et al., 2009). The model in the equation (4.1) is modified as follows by taking natural log of the dependent variable for the first model in the analysis.

$$\begin{aligned} & \ln(APPLICATIONS_i/CAPITA_i) \\ & = TC_i + INC_i + INCSQR_i + HUNTERN_i + AGE_i + AGESQR_i + \mu_i \end{aligned} \quad (4.3)$$

The estimated parameters of the travel cost from the demand function can be used to calculate CS, which is the area under the demand curve between the choke price and the individual's price line (Parsons, 2003). Mathematically, the surplus is the area equal to the negative inverse of the estimated travel cost coefficient in the demand equation. Using the regression results with a transformed dependent variable from equation (4.3), the CS can be easily calculated from reciprocal of the travel cost coefficient ($-1/\beta_{TC}$) (Creel & Loomis, 1990; Loomis et al., 2009).

The ZTCM with zip code rather than the county as zone was used to reduce the aggregation bias due to expected bigger variability in county-level data. The number of applicants per zip code was calculated by summing the applications from each zip code for a year. The approximate expected travel cost, in case the applicants were successful in the lottery, was calculated using the CDXZipStream, an Excel add-in, which analyzes zip code data and calculates the driving distance and time of applicant's resident and the NCWMA. Following Reeling et al. (2016), centroid point of the NCWMA was used to calculate travelling distance because applicants do not know the location of the hunt site until lottery selects them. Only the cost of gas, depreciation, and upkeep costs such as oil, repairs, maintenance, tires were considered for mileage rate following previous hunting studies (Knoche & Lupi, 2007) and fixed costs such as insurance was not included in the mileage rate. The average vehicle operating cost per mile between 2015 and 2017 was \$ 0.45 for a pickup truck (American Automobile Association [AAA], 2018) and the mileage rate is within the range of values used in other recreation studies (Hussain et al. 2016, Knoche & Lupi, 2013; Knoche & Lupi, 2007; Smith & Moore, 2012). The treatment of travel time is one of the most difficult issues in computing trip cost (Parsons, 2003), and it is still debatable in TCM studies (Martínez-Espiñeira & Amoako-Tuffour, 2008; Randall, 1994; Zawacki et al., 2000). The most commonly used practice in travel cost studies is to value travel time at the full or a third of the hourly wage rate (Knoche & Lupi, 2007; Parsons, 2003; Phaneuf & Smith, 2005). Therefore, two travel cost variables were constructed based on two different assumptions of wage rate (no wage rate and a portion (1/3) of reported wage rate) to calculate the opportunity cost of time. The first travel cost variable (TCOST1) was constructed using cost required to travel without considering the opportunity cost

of time (i.e. travel cost was the product of round-trip driving distance and mileage rate plus application fee and license fee). The second travel cost variable (TCOST2) was constructed by summing TCOST1 and one third of the wage rate multiplied by the total time spent for round trip, where the wage rate was calculated by dividing zip code level average annual household income by total number of working hours (2080) in a year (Loomis & McTernan, 2014). Following Parsons (2003), the application and permit fees were included in the travel cost variable. The application fee for an elk permit was \$13, whereas the hunting license fee was \$27 and \$300 for resident and non-resident applicants respectively. Every applicant has to pay the application fee but the license permit fee is only applied to the applicants selected in the lottery.

The number of applicants for a year, represented by *APPLICATION*, for elk hunting permit between 2015 and 2017 was modeled as the dependent variable of the demand model. The explanatory variables included two travel cost alternatives (*TCOST1* and *TCOST2*) as described above, average household income of each zip code (*INCOME*), a quadratic variable to capture any non-linear relation between income and demand (*INCSQ*), total population of each zip code (*POPULATION*), total number of big game hunters of zip code (*HUNTERN*), and an average age of the applicants of the zip code (*AGE*). A quadratic term for age (*AGESQR*) was used to capture any potential curvilinear relation between number of applications and age as it is often the case with recreation models for outdoor recreation and participation (Bowker et al., 2012). The definition and descriptive statistics of the variables used in the models are reported in Table 4.1. Totaling 1,771 observations available for final analysis with each observation representing applications for a permit at least once from a zip code during the study period, the

average number of applications from each zip code was 13.2. The average cost of two-way travel including application fee and permit fee between applicant's zip code to NCWMA ranged from \$258 and \$312 based on the assumption of wage rate.

Table 4. 1 Definition, and descriptive statistics of variables used in travel cost model of demand for elk hunting in Tennessee (N=1,771)

Variable	Definition	Mean	Std. Dev.	Min	Max
APPLICANT	Number of applicants per zip code per year	13.2	18.3	1	137
TCOST1	Travel cost without opportunity cost	257.9	163.3	40.9	946 .1
TCOST2	Travel cost with opportunity cost (33% wage rate)	312.2	205.6	41.2	1126.7
INCOME	Average household income by zip code in thousands	46.8	27.9	19.8	84.91
AGE	Average age of the applicants	47.1	9	13	86
POP	Population by zip code in thousands	10.5	13	0.24	84.9
HUNTERN	Average big game hunter by zip code	228.1	219.4	1	1430.3
YR15	Dummy variable, 1 if the application was received in 2015	0.34	0.47	0	1
YR16	Dummy variable, 1 if the application was received in 2016	0.33	0.47	0	1

On average, household income was \$47,000, and the number of hunters per zip code was 228. The average age of the applicant was 47. About an equal number of applicants applied for the lottery every year.

4.5.2 TCM with adjustment for a lottery-rationed permit

One of the important components in analyzing lottery-rationed permit is the odds or the subjective probability of winning (Scrogin & Berrens, 2003). The hunting lottery model developed by following Nickerson (1990) and Scrogin et al. (2000) were followed and modified in the second model as this study studied single site lottery compared to multi-site lotteries in both of the studies. The probability of each applicant being drawn was denoted by δ_j for S_j being the number of permits to be issued for year j and N_j represents total number of applicant for year j . Let assume $V_{j,i} (Y, P, H, Z)$ be the amount an individual i would be willing to pay for hunting permit with certainty where Y represent individual i 's income, P represents travel cost to travel between individuals home to hunting site, and H represents individual's socio-economic characteristics. Similarly, P_E be the non-refundable entry fee, P_T be the cost spent during the travel, and P_P be the permit fee be the paid by the applicants after being successful in the lottery.

The expected value of entering and being drawn for a permit for year j is $\delta_j [V_{i,j} (.) - P_E - P_{T,i} - P_{P,i}]$ and expected value of not being drawn for year j is $(1 - \delta_j) P_E$. Therefore, the expected value of entering the lottery for year j is sum of the expected values of possible outcomes:

$$E(V_{i,j}) = \delta_j [V_{i,j}(Y_i, P_i, H_i, z_j) - P_E - P_{P,i} - P_{T,i}] - (1 - \delta_j) P_E \quad (4.4)$$

Under the assumption of individual being risk neutral, the individual would participate in the drawing if the expected value is greater than or equal to zero.

$$E(V_{i,j}) = \delta_j [V_{j,i}(Y_i, P_i, H_i, Z_j) - P_{P,i} - P_{T,i}] - P_E \geq 0 \quad (4.5)$$

The expected value of the hunt can be derived by summing the expected value of hunt across the applicants N_j :

$$\text{Total expected net benefits} = \delta_j \sum_{i=1}^{N_j} V_{j,i} - \delta_j \sum_{i=1}^{N_j} P_{T,i} - (S_j P_{P,i} - N_j P_E) \quad (4.6)$$

where, first term is the sum of values an individual would be willing to pay for year j with certainty and the second term is total travel cost, with both terms weighted by the probability of success. The third term in the parentheses is the cost associated with permit and entry fee, respectively.

Using the equation (4.6) and applying truncated negative binomial regression, Scrogin et al. (2000) derived the following formulate to calculate the CS of an opportunity to received a permit per zone (zip code) that account the subjective probability of winning the hunting permit:

$$CS_{\text{lotteryrationed}} = - \frac{e^{x_L \hat{\beta}}}{\delta_j * \hat{\beta}_{TC}} \quad (4.7)$$

where, $e^{x_L \hat{\beta}}$ represents the expected value of the visits when travel cost equals proportion of travel cost depends on δ_j i.e., when travel cost variable = δ_j *mean of travel cost, δ_j is the

subjective probability of individual's being selected for the lottery for year j , and $\hat{\beta}_{TC}$ is the coefficient of the travel cost variable in the model.

Equation (4.5) can be used to calculate CS of the unconstrained demand of elk permit i.e., when every applicant gets a chance to hunt instead of being selected in the lottery. Therefore, the equation gives Marshallian CS if ($\delta_j = 1$) and the CS of opportunity of receiving a permit per zip code is given by:

$$CS_{Marshallian} = -\frac{e^{x^m \hat{\beta}}}{\hat{\beta}_{TC}} \quad (4.8)$$

Where, $e^{x^m \hat{\beta}}$ is the expected value of the demand model when mean values of the independent variables are considered and $\hat{\beta}_{TC}$ is the coefficient of travel cost variable.

4.6 Data

The elk hunting permit application dataset for Tennessee for 2015 –2017, obtained from TWRA, was the primary source of data. The application database came with zip code and birth year of each applicant. Similarly, the number of big game hunters and big game hunter's age for each zip code were also obtained from TWRA. The adjusted gross household income and total population at a zip code level were obtained from the Internal Revenue Service (IRS).

4.7 Results and discussion

4.7.1 Regression estimates

Regression estimates of permit demand models are presented in Table 4.2 and Table 4.3. Both the linear regression with semi-log dependent variable and the zero-truncated negative binomial regression with a number of application per zip code per year were estimated, and the sign of the variables was consistent across the models. In the second model, when TCM adjusted for lottery rationed permit, the likelihood ratio test of over-dispersion rejected the null hypothesis that the mean and variance of the dependent variable are equal, justifying the use of the truncated negative binomial model over the truncated Poisson regression. In addition, the negative binomial model had lower Akaike Information Criteria (AIC) statics than the Poisson model. For brevity, only the truncated negative binomial regression is reported. The sign of most of the variables was consistent with economic theory and results from previous studies, and all coefficients were significant at either 5% or 10% except for the dummy variables for year.

Table 4. 2 Regression estimates from alternative models of elk hunting demand in Tennessee, by the alternative assumption of wage rate from modified zonal travel cost method (N= 1,771)

Variable	No wage rate	33% wage rate
TCOST1	-0.0047**(0.0002)	-
TCOST2	-	-0.0038**(0.0002)
INCOME	0.032* (0.019)	0.038**(0.019)
INCOMESQR	-0.0005** (0.0002)	-0.001**(0.0002)
AGE	0.178**(0.019)	0.186**(0.019)
AGESQR	-0.002**(0.0002)	-0.002** (0.0002)
HUNTERN	0.0005**(0.0001)	0.001**(0.0001)
YR15	-0.038 (0.063)	-0.043 (0.064)
YR16	-0.026 (0.063)	-0.027 (0.065)
CONS	-2.91** (0.65)	-3.34** (0.665)
Adjusted R ²	0.41	0.39
AIC	5321.4	5380.3

Note: ** and * indicates statistical significance at 5% and 10% level, numbers in parentheses are standard errors.

Table 4. 3 Regression estimates from alternative models of elk hunting demand in Tennessee, by the alternative assumption of wage rate for travel cost method with adjustment for a lottery-rationed permit (N=1,771)

Variable	No wage rate	33% wage rate
TCOST1	-0.055** (0.0002)	-
TCOST2	-	-0.0044** (0.0001)
INCOME	0.086** (0.011)	0.09** (0.002)
INCOMESQR	-0.001** (0.00001)	-0.001** (0.0001)
AGE	0.45** (0.03)	0.455** (0.037)
AGESQR	-0.005** (0.0003)	-0.005** (0.0004)
HUNTERN	0.003** (0.0001)	0.003** (0.0001)
YR15	-0.031 (0.039)	-0.031 (0.034)
YR16	-0.007 (0.037)	-0.007 (0.034)
CONS	-9.88** (0.68)	-10.18** (0.869)
Pseudo R ²	0.22	0.22
AIC	5242	5287

Note: ** and * indicates statistical significance at 5% and 10% level, numbers in parentheses are standard errors.

The estimated coefficient on travel cost (TCOST) was significant at $p < 0.05$ and the sign was negative as expected in both models of the alternative cost of time assumptions. This suggests that the elk hunting permit demand decreases with increased travel cost. The negative relationship between the demand and the price of the travel is in line with the economic theory of demand and is consistent with past outdoor recreation studies (Bergstrom & Cordell, 1991; Bowker, English, & Donovan, 1996; Loomis & McTernan, 2014) and previous big game hunting studies (Duffield, 1991; Loomis, 1982; Scrogin et al., 2000). The positive sign of income (INC) and negative sign of quadratic term (INCSQR) was significant at $p < 0.1$ suggests that demand for elk hunting increases with household income but at a decreasing rate. This result is consistent with results reported by previous elk hunting studies although some studies had found contrasting results about the effect of income on recreation demand (Sorg & Nelson, 1986). Previous studies on wildlife recreation demand have also found a negative effect of income on demand (Balkan & Kahn 1988; Creel & Loomis, 1990; Zawachi et al. 2000).

The coefficients on age (AGE) and the square of age (AGESQR) were significant at $p < 0.05$ and signs were positive and negative, respectively. This result showed the non-linear effect of age on hunting demand. Age seems to have a curvilinear relationship with the demand for elk hunting. The U-Shaped relationship means the demand increases with age at a decreasing rate. The positive coefficient on hunters number (HUNTERN) at $p < 0.05$ suggests that demand for elk hunting is likely to be higher in the zip code with larger big game hunters population. Similar findings regarding the number of people from each zone were reported by Sorg and Nelson (1986). The coefficient on year dummies for the year 2015 and 2016 was statistically

insignificant across the models, suggesting that the demand for elk hunting in 2017 is not different from previous years.

4.7.2 Economic welfare estimates

Using the modified ZTCM, the economic value of the opportunity of receiving an elk hunting permit per person was derived by taking the reciprocal of the travel cost coefficients presented in Table 4.2. The CS value per person with no opportunity cost of time assumed was \$212. Following past studies (Kling & Sexton, 1990; Martínez-Espíñeira & Amoako-Tuffour, 2008), the lower and upper bounds of the confidence interval of the price coefficient were calculated through bootstrapping the standard errors. Therefore, the corresponding 95% confidence interval of CS per person through bootstrapping was \$197 and \$228. When the wage rate was assumed, the estimated CS per person was \$260 with 95% confidence interval of \$241 and \$281.

In the second model, TCM with adjustment for a lottery-rationed permit, the benefits estimates depend on the assumption of opportunity cost of time and the subjective probability of applicant being successful in the lottery. The permit applicants do not have prior knowledge about the number of applicants in Tennessee, i.e., their chances of winning a permit. The prediction of the applicants' chance of success is difficult because many cognitive and social-psychological factors affect the lottery play (Rogers & Webley, 2001). Following the Equation (4. 8) suggested by Scrogin et al. (2000) and assuming the δ to be 0.5, CS per person was estimated to be \$284 (95% confidence interval of \$269 and \$300) and \$352 (95% confidence

interval of (\$336 and \$369) for the model without opportunity cost and for the model when 33% of the wage rate as opportunity cost of time, respectively. The assumed probability of success may not represent the actual perception of odds among the permit applicants. However, 0.5 was chosen with the assumption that the population of permit applicants with respect to expected success follows a normal distribution, with fewer people being extremely optimistic or extremely pessimistic. Equation (4.8) calculates the CS of the opportunity of winning a permit per zip code per hunt and CS per person was calculate by dividing the CS value from equation (4.8) by dividing the average number of applicants per zip code (13.2) provided in Table 4.1. If a lottery applicant's chance of winning the permit is assumed to be certain, when $\delta=1$, the traditional Marshallian measure of economic benefits can be calculated as shown in the equation (4.9). Therefore, when δ was assumed to be 1, the CS per person was found to fall between \$181 and \$226 based on the assumption of opportunity cost of time. The net benefit was found similar for both modified ZTCM and TCM with adjustment for a lottery-rationed permit. Therefore, the former method can be used instead of latter when the subjective probability of hunters' chances of being selected is unknown.

Estimates of net benefits from this study are within the range of value estimates reported in previous studies, but the values from previous studies vary. The observed variation in estimates of benefit in previous studies is attributable to many factors, including the method used (TCM or CV method), the location of study area, the population of elk and number of permits available, and type of expenditure included in the travel cost variable. A recent benefit transfer study utilizing estimates from 12 studies found the mean value of elk hunting to be \$103 per

person per day, with lowest and higher values being \$27 and \$367 in CV studies per person per day, respectively (Rosenberger et al. 2016). Among the travel cost studies, they found the mean value of per person per day CS of \$91, with \$58 and \$153 being the lowest and highest values respectively. Most recently, Aiken (2015) analyzed hunting trip expenditure data from National Wildlife and Fish related recreation survey data from five states (Colorado, Idaho, Montana, Oregon, and Wyoming) and estimated the net willingness to pay for elk hunting to be \$109 with median value being \$102. The net economic values were developed for current resource condition and hunters' expenditure included cost of gasoline, transportation, food, and lodging in his analysis.

Of travel cost studies estimating the economic value of elk hunting with permit data, only Scrogin (2000) estimated the benefits under a lottery. Most of the elk hunting valuation studies were conducted in the 1980s and 1990s, when rationing was not a common practice in managing elk hunting with a lottery system. Using the elk hunting lottery application data for two years in New Mexico, they found an increase in economic value from elk hunting in Mexico after the policy changes to favor the New Mexico residents. They estimated net value of the opportunity of receiving a license per hunt per zip code and found an increase in value from \$85 to \$105 when the policy allows more permit to resident hunters. The values were decreased \$18 and \$26, respectively in Marshallian surplus estimation. A list of previous studies on elk hunting, their economic value estimation, study area, and method used are presented in Appendix C.

The per person benefit estimates from Table 4.1 and the average number of applications (13.2) from Table 4.1 were multiplied by a number of zip codes (742) to derive the total net

economic benefits of elk hunting opportunity in Tennessee. The net economic benefits were found to be \$2.07 million (no wage rate assumed) and \$2.54 million (33% of wage rate assumed) for the modified ZTCM. For the TCM model with adjustment for a lottery-rationed permit, the net economic benefits was found to be \$2.77 million (no wage rate assumed) and \$3.44 million (33% of wage rate assumed) when δ was assumed to be 0.5. Table 4.4 provides per person and aggregate benefits of each modelling assumptions.

Following Parsons (2003, p. 291), the discounted net present value of a perpetuity of the site was computed using the aggregate value and assuming no changes in the site characteristics, use of the site, and a constant rate of discount. Assuming a discount rate of 5% (Parsons, 2003), the net present value of the elk hunting opportunity (aggregate economic value/discount rate) was as high as \$50.88 million for the modified ZTCM. In the TCM model with adjustment for a lottery-rationed permit, the net present value was as high as \$68.92 and \$44.23 million when δ was assumed to be 0.5 and 1, respectively. Table 4.5 provides the net present estimation of each modelling assumptions.

Table 4. 4 Consumer surplus of the opportunity of receiving a permit per person in Tennessee, by the alternative assumption of wage rate (2018 dollar)

Model: Modified zonal travel cost method		
	No wage rate	33% wage rate
Marshallian	212 (197, 228)	260 (241, 281)
Model: Travel cost method with adjustment for a lottery-rationed permit		
Subjective probability		
(delta)	No wage rate	33% wage rate
Probability=0.5	284 (269, 300)	352 (336, 369)
Probability=1		
(Marshallian)	181 (171, 191)	226 (215, 237)

Note: Numbers in parentheses are a confidence interval

Table 4. 5 Aggregate consumer surplus and net present economic value of elk hunting in Tennessee, by the alternative assumption of wage rate (millions of dollar)

Model	Probability	Aggregate		Net present value of a perpetuity	
		No wage rate	33% wage rate	No wage rate	33% wage rate
Modified ZTCM	-	2.07	2.54	41.43	50.88
TCM with adjustment for lottery-rationed permit	0.5	2.77	3.44	55.56	68.92
TCM with adjustment for lottery-rationed permit	1	1.77	2.21	35.41	44.23

4.8 Conclusion

This study assessed the net economic benefit of the opportunity of receiving a permit for elk hunting in the North Cumberland Wildlife Management Area in Tennessee by applying a zonal travel cost model to elk permits application data. Although this study followed a similar theoretical model developed by Scrogin et al. (2000), elk hunting in Tennessee is unique in terms of a number of lotteries drawn and permits issued, total elk population, hunting history, and an applicant's knowledge of odds in the lottery. The findings have several implications for improving outdoor recreation demand modeling and understanding the public value of elk hunting. First, the net economic benefit of the opportunity of receiving a permit per person was estimated to be between \$212 and \$352 under different modeling and opportunity cost assumptions. This estimate is very similar to benefits reported in the literature and confirms that elk hunting in Tennessee has a substantial economic benefit to the resident and non-resident hunters, along with ecological benefits of elk population. Since the benefit estimates reported in the literature are mostly based on decades-old studies conducted in the western states, estimates presented in this study uniquely update the elk hunting valuation literature. In fact, this is the only study of elk hunting valuation in the east of Rocky Mountain region.

When aggregated across hunter population, total net economic benefits of the opportunity to hunt elk on the NCWMA ranged from \$2.07 and \$3.44 million annually. Similarly, assuming the annual discount rate of 5%, the net present value of elk hunting opportunity of perpetuity would be as high as \$68.92 million, which characterizes the extent of welfare loss to Tennessee hunters should this site be closed for hunting access. Wildlife agency personnel responsible for

elk management and conservation organizations interested in elk management may find this information useful in characterizing the public value of elk restoration program and comparing benefits with costs of restoration and management. Wildlife managers and decision makers may draw upon the economic value presented in this paper, in a benefit transfer approach, to project the expected benefit of elk restoration programs in their region.

Second, this study further validates the efficacy of modeling approach that relies on permit application data for lottery-rationed recreation. Benefit estimate in terms of consumer surplus per person in this study is similar to values reported in the elk hunting literature that used a variety of methods such as travel cost and contingent valuation. Hence, this convergent validity suggests that the zonal travel cost model for permit application data produces reasonable estimates of benefits associated with recreation access. In particular, this study showed that the modified zonal travel cost model of permit application could be a reliable valuation method when the odds of lottery selection is not disclosed to hunters. A well-regulated hunting that addresses the demand of resident hunters and helps stabilize population could be an effective tool in minimizing human-elk conflict, engaging broader stakeholder groups in conservation and use, and promoting the economic growth of rural communities.

There were some limitations of this study. First, although recent studies involving travel cost modeling have used random utility modeling framework with data on a trip or permit to multiple sites, such a model could not be applied in this case because NCWMA is the only site in Tennessee with elk hunting opportunity. Second, another limitation related to the demand model is that it assumes each successful applicant will take a single trip to hunt elk in the season. While

it is possible that some hunters will make multiple trips, the effect of this modeling assumption in this study may be minimal. This is because unlike other big games (i.e. deer, turkey), the duration of the Tennessee elk hunting season is very short (approximately one week) and hunters may not take too many trips. Third, the estimates are like to be understated because only truncated models are reported excluding zip code without single application because income and age data were missing, in particular, for non-resident hunters and it is reasonable to assume that hunters from every zip code would not apply for a permit in Tennessee. The similar benefit per person values of truncated and non-truncated models for resident hunters also justified the decision to report only the truncated model. Lastly, other important variables such as gender, education, and previous experience which could potentially affect the economic benefits could not be included in the model because such information was not available or was not meaningful in aggregating the data by zone.

CHAPTER 5

SUMMARY AND CONCLUSIONS

Almost half of the population participates in outdoor recreation activities in the United States, making the outdoor recreation industry one of the largest economic sectors in the country. Although recreationists spend billions of dollars for travel and different outdoor products, the expenditure only shows that part of the benefits those recreationists get from the recreation. The economic value of ecosystem services such as opportunity for outdoor recreation is not readily available from market data, partly because unlike market goods or services, amenity benefits are not traded in the market. A number of non-market valuation methods have been developed by resource economists to characterize the net benefit of recreational access to sites of significant resource such as national forests, scenic rivers, or wildlife management areas. The proper estimation of economic benefits recreationists derive by accessing such resources is necessary in full accounting for the benefits and costs associated with resource management strategies. Studies incorporated in this dissertation addressed unique questions in valuation of outdoor recreation by applying various forms of travel cost method and analyzed demand for and economic value of three different types of recreation activities.

The first study built upon the existing model of individual travel cost by adding destination-based climate information to analyze and project potential effect of climate change on demand for and economic value of downhill skiing and snowboarding. The novelty of this study lies on the application of a robust travel cost model to nationwide data of ski visitors, and integrating site-specific climatic data with visitor-specific trip profile and demographic data. The net benefit of access to national forests for downhill skiing was substantial with per person per trip net economic benefit ranges from \$91 to \$185 depending on the assumptions about skiers’

opportunity cost of time. Aggregation of this across the U.S. National Forest system leads to a total of \$4.39 billion annually, implying that skiing on national forests can generate substantial economic benefits for the public. Second, climate variables including temperature, snow depth, and rainfall were correlated with ski demand, and projected changes in these climate variables could affect the economic benefits from skiing. Combining model parameters with projected climate data in future indicate that the potential loss in net benefit due to decline in participation could be as high as \$374 million by 2060.

Findings of this study contribute to understanding the net economic benefit of maintaining downhill skiing on national forests. Projections will guide the long-term planning of ski areas in the national forest to optimize benefits in the context of climate change as our results show recreational benefits constitute a large share of benefits, and it will likely decrease considerably in the future. More importantly, the results can be used to inform planners and possibly enhance public support to carry out climate change adaptation and mitigation measures by the ski industry and relevant public land managers.

The second study delved into comparison of Wild and Scenic Rivers designated and non-designated rivers in terms of demand for and value of non-motorized boating access. Along with protecting the rivers with outstanding values, these rivers also provide recreation benefits to society. Previous studies have examined these designated rivers in many aspects, but none assessed the effect of designation on the demand and economic value of recreational access to those rivers for popular activities such as non-motorized boating. In addition, only a couple of travel cost studies focused on analyzing value and demand of non-motorized boating using

national-level data (Bergstrom & Cordell, 1991; Bowker et al., 2009) but the generalizability of those results is limited. Considering the large number of non-motorized boaters in the national forest annually, credible and broadly applicable information on what factors influence the demand for and value of recreational access for non-motorized boating, and how river designation status and other river characteristics impact demand as well as value is needed.

The economic benefit from accessing the national forests for non-motorized boating trips per person per trip was estimated to be between \$66 and \$87 depending on the modeling assumption about boaters' opportunity cost of time. Nationwide, the total annual economic value ranged from \$108.24 to \$142.68 million, indicating that non-motorized boating activities on national forests can generate considerable economic benefits. Second, the congressional designation of rivers under the National Wild and Scenic River Act of 1968 did not signal different demand for and value of non-motorized boating between designated and non-designated rivers. However, site characteristics such as ramp availability, camp size, difficulty level were found to be significantly correlated with demand for non-motorized boating. These findings may be useful in enhancing the recreational appeal of rivers for non-motorized boaters and in understanding the value of non-motorized boating on public lands in general and national forests in particular. Such information will be helpful to management agencies such as the US Forest Service as the estimation demonstrated substantial benefits of non-motorized boating in the national forest. Considering the 50th anniversary of the Wild and Scenic Rivers Act in 2018, the results could be helpful to develop management plans that balance recreational demand along with protecting the river values and maintaining water quality.

The third study dealt with a unique issue of valuation in which recreation access was controlled with a lottery-based permit system to hunt elk in North Cumberland Wildlife Management Area, Tennessee. Unlike the first two studies, a trip-based travel cost model was not appropriate in this case because very few people were selected by the random lottery and were able to hunt elk. This challenge was addressed by improving the existing zonal travel cost models of recreation demand that utilized permit application as indicator of demand for site access. The estimated per person per trip net economic benefit of the opportunity of receiving elk hunting permit was between \$212 and \$352, depending on the modeling assumptions, and the total benefit of elk hunting opportunity was found to be as high as \$3.44 million. A methodological implication for this study is that a zonal travel cost model of permit demand could produce reasonable estimates of benefits of site access when demand is regulated with lottery system. The findings should help management agencies such as the Tennessee Wildlife Resource Agency understand the economic significance of elk hunting opportunity and to educate the public on value of restoration programs.

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APPENDIX

Appendix A Previous studies on consumer surplus of downhill skiing and snowboarding (2016 dollars)

Study	Study area	CS	Unit	Method	Data
Downhill skiing					
Cicchetti et al. 1976	Six ski areas in CA	27	Per trip	ZTCM	Visit rates from Forest Service
Walsh & Davitt 1983	Aspen ski resort, CO	59	Per trip	ITCM	Interview of 837 skiers
Walsh et al.1983	Three ski areas in CO	45	Per trip	WTP	Interview with 236 skiers
Morey 1984	15 ski areas in CO		Per trip	CES ⁺ , GCES	Interview with 163 students
		43,79			
Morey 1985	15 ski areas in CO		Per trip	CES, GCES	Interview with 163 students
		14,26			
Bergstrom & Cordell 1991	United States		Per trip	ZTCM	Public Area Recreation Visitors Study
		62			
Mendelsohn & Markowski 1999	United States		Per day	Linear/log linear demand function	Statewide participation data
		32			
Loomis & Crespi 1999	United States		Per day	BTA	Estimates from Bergstrom and Cordell (1991)
		30			
Rosenberger & Loomis 2000	United States	43	per day	BTA	Based on 5 studies
Englin & Moeltner 2004	13 ski resorts, NV		Per trip	ITCM	Interview with 131 students
		98			
Loomis 2005	United States	43	Per day	BTA	Based on 5 studies

Study	Study area	CS	Unit	Method	Data
Bowker et al. 2009*	United States	162-234	Per trip	ITCM	120 national forests and grasslands
Snowboarding					
Englin & Moeltner 2004	13 ski resorts in NV	48	Per trip	ITCM	Interview with 131 students

Note: ⁺CES refers to Constant Elasticity of substitution and GCES refers to Generalized Elasticity of Substitution.

* Bowker et al. (2009) used both skiing and snowboarding data to estimate CS

Appendix B Previous studies on net economic value of non-motorized boating in the United States (2017 dollars)

Study	Study area	CS	Unit	Method	Activity	WSR Designation
Bowker and English 1994	Middle Fork Salmon River, ID	439-560	Per person day	ITCM	Guided rafting	Yes
Siderelis and Moore 2006	Chattooga River, GA and SC	204	Per person per trip	ITCM	Guided rafting	Yes
Siderelis and Moore 2006	Chattooga River, GA and SC	155	Per person per trip	ITCM	Kayaking	Yes
Walsh, Sanders, Loomis 1985	Rivers, CO	45	Per household	CV	River recreation	Yes
McKean, Johnson, Taylor, 2012	Snake River reservoirs, WA	61	Per person per trip	TCM	Boating	No
McKean et al, 2005	Lower Snake River, WA	27	Per person per trip	TCM	Boating	No
Ready and Kemlage, 1998	Gauley River, WV	128	Per person per trip	Zonal TCM	Private paddling	No
Ready and Kemlage, 1998	Gauley River, WV	55	Per person per trip	Zonal TCM	Commercial rafting	No
Bergstrom and Cordell 1991	Nationwide	67	Per person per trip	Zonal TCM	Rafting/tubing	No
Bergstrom and Cordell 1991	Nationwide	45	Per person per trip	Zonal TCM	Canoeing/Kayaking	No

Study	Study area	CS	Unit	Method	Activity	WSR Designation
Bergstrom and Cordell 1991	Nationwide	92.11	Per person per trip	Zonal TCM	Rowing/Boating	No
Loomis, 2003	Snake River, WY	33	Per person day trip	TCM	Rafting	No
Bowker, English, and Donovan 1996	Chattooga River, GA and SC	198-301	Per person per trip	TCM	Guided rafting	Yes
Bowker, English, and Donovan 1996	Nantahala River, NC	147-206	Per person per trip	TCM	Guided rafting	No
Siderelis, Whitehead, and Thigpen, 2001	Rivers in NC	39	For annual pass	CVM	Water trail users	No
McKean et al., 2005	Lower Snake River reservoirs, WA	27	Per person per trip	TCM	Boating	No
Loomis and McTernan 2014	Poudre River, CO	108	Per person per trip	CVM	Boating	Yes
Loomis and McTernan 2014	Poudre River, CO	115	Per person per trip	TCM	Boating	Yes

Appendix C Previous studies on net economic value of elk hunting in the United States (2018 dollars)

Study	Study area	Remarks	CS	Unit (per)
Model: Travel cost				
Scrogin 2000	New Mexico	Lottery rationed	88-110	zip code per hunt
Scrogin 2000	New Mexico	Marshallian	18-28	zip code per hunt
Duffield 1988	Montana	2.8 days per trip	418	trip
Duffield 1988	Montana	2.8 days per trip	149	day
Sort & Nelson 1986	Idaho	standardized TC	162	trip
Sort & Nelson 1986	Idaho	Reported TC	258	trip
Model: Contingent valuation				
Aiken 2016	National		109	day
Aiken 2009	National		101	day
Fried et al. 1995	Oregon		473	trip
Sort & Nelson 1986	Idaho	present condition	131-234	trip
Sort & Nelson 1986	Idaho	Present condition	46-57	day
Sort & Nelson 1986	Idaho	doubling the elk seen	378	trip
Park et al. 1991	Montana	present condition	270	trip
Park et al. 1992	Montana	doubling the chance of hunt	383	trip
Park et al. 1993	Montana	reduced crowding condition	302	trip
Bolon 1994	Oregon		217	trip

Study	Study area	Remarks	CS	Unit (per)
Bolon 1994	Oregon		71-143	day
Cory & Martin 1985	Arizona	Present condition	138	trip
Loomis et al. 1988	Montana	present condition	595	trip
Loomis et al. 1988	Montana	present condition	84	day
Loomis et al. 1988	Montana	chance of harvesting double	780	trip
Loomis et al. 1988	Montana	chance of harvesting double	123	day

VITA

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