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Special Issue

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 over 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 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

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billion, annually. 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. Findings contribute to understanding the net economic benefit of maintaining downhill skiing on national forests, and will help recreation planners and tourism entrepreneurs develop adaptive strategies to sustain the skiing industry.

Keywords

Economic valuation, travel cost, consumer surplus, downhill skiing, national forests, climate effects

Downhill skiing and snowboarding are the most popular winter recreation activities in national forests in the United States. The U.S. Forest Service (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), about one-fourth are inside national forest boundaries. 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, with 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.

Average annual skier and snowboarder visits is 56.5 million in the United States (NSAA, 2016), and 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 and spend in local economies (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 (revenues) from national forests, it does not capture the net economic value resulting from 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 for and economic value of 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 of small sample size and failure to account for factors such as climatic conditions. To fill this knowledge gap, 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.

Previous Studies of Demand for and Value of Downhill Skiing

Cicchetti, Fisher, and Smith (1976) used an aggregate, or zonal, travel cost model to estimate the consumer surplus (CS), a monetary measure of net benefit, associated with the development of proposed Mineral King Project in California, and found per trip CS of $27 (all CS estimates reported in 2016 dollars). 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) 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.

Bergstrom and Cordell (1991) is the first study to estimate national-level economic value of downhill skiing where they used Public Area Recreation Visitors Study (PARVS) data from 200 sites on public lands. Moreover, Bowker et al. (2009) employed the travel cost method (TCM) to NVUM's Round 1 data (2000 to 2003) and found a net economic value in the range of $162 to $234 for downhill skiing. Other researchers have used alternative valuation methods such as contingent valuation (Walsh, Miller, & Gilliam, 1983) and benefit transfer approaches (Loomis & Crespi, 1999; Rosenberger & Loomis, 2001) 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 willingness to pay (WTP) for lift tickets, contingent on changes in the number of skiers per acre, and found per trip WTP of $45.

Effect of Climatic Factors on Downhill Skiing Participation

Climate change is expected to affect many types of outdoor recreation activities in the future (Scott, Jones, & Konopek, 2007). 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. A number of studies have analyzed participation and trip demand for skiing in the United States (Englin & Moeltner, 2004; Hamilton et al., 2007; Moeltner & Englin, 2004; Shih et al., 2009), but few studies have assessed the impact of climate factors. 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. A time series analysis of Austrian ski area visitation by Töglhofer et al. (2011) reported a positive relationship between overnight stays and good snow conditions, but the overnight stays at higher elevation were found independent of weather variables. Dawson and Scott (2013) also found that the effect of climate on ski demand at higher elevations was not significant. Falk (2010) found the positive effect of snow depth on resort stay to vary with slope and elevation. 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.

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%) and $4.6 billion (62%) 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 a decrease in snow depth up to 100%. Englin and Moeltner (2004) applied TCM to estimate a demand model for 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.

Objective and Significance of the Study

Our primary research objectives were to estimate the demand for and economic value of downhill skiing in national forests, and to analyze the effects of projected climate change on this demand and economic value. Previous findings have been limited in scope (e.g., small sample sizes, specific study areas, etc.) or used methods that are arguably less robust than 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, but their findings were based on data from a relatively small and limited sample of 131 college students visiting resorts around Reno, Nevada. Although they found significant impacts for 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 their NUVM Round 1 data are considered limited due to inconsistency in implementing field data collection protocols. Along with including climate variables in the model, our study projects the effect of climate change on ski participation and the economic benefits from downhill skiing in the future.

Downhill skiing relies to a large extent on climatic conditions. However, skiers can alter the destination and timing of their trips or substitute another activity depending on weather conditions (Scott, McBoyle, & Minogue, 2007). Origin-specific climatic factors are best suited to analyses of local activities such as hiking and fishing that 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 longer travel to a site where the climatic conditions are often 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 few ski destinations. Hence, using destination specific climatic data in combination with trip data collected from a nationwide survey of visitors is another unique feature of our study.

Methods

Econometric Model

The TCM has been the most commonly used revealed preference technique when valuing access to public land for recreation purposes. TCM assumes that the costs of traveling by an individual or group to a 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).

Consistent with a typical demand model, the empirical model of demand for downhill skiing trips to national forests was specified as follows:

$$TRIPS_{ik} = f\begin{pmatrix} TC_{ik}, ROCKY_k, SUB_{ik},\ SE_{i,} PEOPVEH_{ik}, \\ UNDER16_{ik}, TIME_{ik}, RECESSION, ROUND, CL_k,\ El_k \end{pmatrix} + \mu_{ik} \quad (1)$$

Where, $TRIPS_{ik}$ represents the 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 k 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 k.The term ui_k is random error.

Following Sardana, Bergstrom, and Bowker (2016), we used annual number of trips by an individual or group as dependent variable. The mileage rate was set at the variable operating costs including gas, maintenance, and tires (Parsons, 2017, p. 215). The average variable operating cost of a medium sedan was $0.177 (American Automobile Association [AAA], 2017).Valuing travel time at the wage rate or some fraction of it as is typical (Englin & Moeltner, 2004), we constructed two travel cost variables 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 and McTernan (2014), the wage rate was calculated by dividing annual household income by total number of work 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 (Englin & Moeltner, 2004). Parsons (2017, p.215) stated that typically only a daily fee is used for the travel cost variable, and accounting for annual, season, or weekly passes is difficult and generally ignored, or possibly incorporated into the participation portion of a two-stage model. A large dataset like NVUM does not contain the type of details often available at single-site or multiple-sites in a given market. For skiing, ticket pricing varies throughout the season, although many skiers purchase season passes (NSAA, 2017). Lift ticket prices may vary by weekend or weekday, half-day or full day or two-day ticket, and by age of the skiers. Other factors such as complimentary ticket rates, promotional rates, pre-purchase deals, online ticker 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, we added a binary variable to denote Rocky Mountain region visits. This region covered eight states (Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming) in the Rocky Mountain region.

Many aspects of travel cost modeling have been debated including on-site time (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 thoretically 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). For this reason, we included on-site time in the demand model.

The climatic variables included in the model were, *STEMP*, seasonal monthly mean temperature in degree Celsius (°C) at the ski site, "*SSNOWDEPTH*," monthly seasonal maximum snow depth in centimeters within a month at the ski site, and, *SRAIN,* seasonal average monthly rainfall at the ski site in millimeters. Because Englin and Moeltner (2004) found a non-linear relation between ski demand and snowfall, we also added a quadratic of snow depth, "*SSNOWDEPTHSQR*," to see if their result holds for national level estimation.

The estimated travel cost parameter from the demand function is used to calculate net benefit or CS associated with accessing ski areas. The average per group CS per trip can be derived from the truncated count data estimator as the negative inverse of the estimated travel cost coefficient ($-1/\beta_{TC}$). Dividing that value by the average number of people per group yields the CS per trip per person.

As a part of the 2010 USDA Forest Service RPA Assessment, Joyce et al. (2014) presented U.S. climate futures based on projections of population growth, economic growth, and land use change associated with scenarios (A1B, A2, and B2) from the IPCC Special Report on Emissions. 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. For the reasons discussed in Poudyal, Elkins, Nibbelink, Cordell, & Gyawali, (2016), we chose the projected seasonal mean temperature and seasonal mean precipitation data for A1B scenario for the counties where skier information was collected. For 2060, the projected mean temperature change was +2.72°C and +4.25 mm for precipitation. Since they did not project snow depth for 2060; we estimated snowfall by location for 2060 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.

We predicted the conditional mean of ski visits with a truncated negative binomial regression following Cameron and Trivedi (2012, p. 131). Following Heberling and

Templeton (2009), we estimated the difference in expected number of trips in 2016 and 2060 and calculated the difference in trips due to projected climate variable changes in 2060, assuming other factors affecting the demand for skiing remained constant. The percentage change in CS due to climate change can be defined as:

$$\Delta CS = \left(\frac{E(y_i|x_i) - E(y_i|x_i)_{CC}}{E(y_i|x_i)}\right) * \frac{-\left(\frac{1}{\beta_{TC}}\right)}{PEOPVEH_i} * NAV \qquad (2)$$

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 NVUM rounds 2 and 3.

Trip data collected on-site can lead to the well-documented problems of non-negative integer counts, truncation, and endogenous stratification (Shaw, 1988). Estimators are biased if these problems are not addressed properly (Hausman, Hall, & Griliches, 1984). In addition, data on on-site visits are usually overdispersed (i.e., the conditional mean and variance are unequal) resulting in inconsistent and inefficient parameter estimation for truncated Poisson model (Cameron & Trivedi, 2012). To address these issues, truncated negative binomial model have been used in previous recreation demand studies using on-site interviews (Martínez-Espiñeira & Amoako-Tuffour, 2008; Yen & Adamowicz, 1993). However, Dobbs (1993) and Shrestha, Seidl, and Moraes (2000) found that adjustment for endogenous stratification had an insignificant effect on the estimated coefficients and CS. Therefore, our data analysis only addressed the issue of overdispersion and truncation.

Data

Trip profile data were obtained from the NVUM, which is intended to estimate the volume of recreation use on national forests. The NVUM survey collects data from randomly selected last-exiting recreationists on such variables as trip frequency, expenditures, and demographics. The data for our analysis were collected from 2005 to 2014, totaling 16,095 recreation visit observations, making it one of the larger data sets among TCM studies. A detailed discussion of NVUM sampling and survey procedures is available in English, Kocis, Zarnoch, & Arnold (2002).

Annual primary purpose downhill skiing (downhill skiing or snowboarding) visits was the dependent variable in the demand model. Some adjustments were performed on the dataset due to theoretical and empirical reasons. Multi-purpose 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, 2017), we followed accepted protocol and only included observations with downhill skiing as the primary purpose, and visits from foreign countries, and outside the conterminous United States (Alaska, Hawaii, Puerto Rico, Virgin Islands) were not included. Long distance travelers are not well described by the recreational demand model as they primarily use air travel which often has low correlation between cost and distance travelled. We also trimmed observations if one-way distance traveled was greater than 1,000 miles, a procedure used in numerous other studies (Hellersetin, 1991).

Substitute variable definition in travel cost modeling is a challenge. The economics module of the NVUM questionnaire, distributed to only about 1/3 of the sample, included a qualitative question about substitutes for the current visit. 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 (Rosenthal, 1987).Various approaches have been used for substitutes TCM, including the price of a nearby substitute (Sardana et al., 2016), a dummy variable indicating whether or not a respondent intend to visit a substitute site (Martínez-Espiñeira & Amoako-Tuffour, 2008), number of trips to substitute sites (Loomis & McTernan, 2014), and using a substitute index based on recreation opportunities available (Bergstrom & Cordell, 1991).We used a heuristic rule choosing the nearest downhill skiing site to a visitor's origin and constructed a substitute equal to the one-way distance from visitor's origin to the nearest ski site not visited on the current trip. This approach is a compromise when someone is traveling to a skiing destination seeking an experience different than his/her local ski area (e.g., an iconic destination). Ski sites inside and outside national forests boundaries were considered.

Skiing in the United States is not a year-round activity. The National Ski Areas Association's reports, on average, ski areas open 159 days per season from 2004 to 2008 (NSAA, 2008) and from 2012 to 2014 (NSAA, 2014) to be as high as 159 days. Hence, reported trips higher than 159 were trunctated. Such truncation is typical (Sardana et al., 2016). Observations with a party size more than 10 were deleted because large-group travel is likely at a different cost per mile. Ski site location is important for calculating travel distance and combining site-specific climate data, but 2,420 observations did not have latitude/longitude information. These missing values were replaced by the zip code of the closest ski site within that 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 the economics module is administered to about one-third of those surveyed (USDA Forest Service, 2007).To enhance sample size, but minimize the potential bias due to missing income, we followed Mingie, Poudyal, Bowker, Mengak, and Siry (2017) and Kim, Shaw, and Woodward (2007), and estimated a household income proxy from data in the basic survey (administered to all) 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: household income = - 53441.5 + 1080.8(gender binary, male=1) + 0.14 (IRS's gross income) + 4987.1(age) - 45.2 (age square) + 6890.6 (number of people under 16 in the travelling group), $R^2 = 0.27$). The predicted income proxy was used in the travel cost demand function.

NVUM data do not contain mode of transportation and type of a 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 (travel distance more than 1,000 miles, large traveling groups, ski visits during offseason, total annual visits more than season length), and dropping observations with missing values of key variables, a total of 8,974 observations were analyzed. The mean values of important variables in original and trimmed datasets were not statistically different.

Historical monthly climate data from the National Oceanic and Atmospheric Administration's (NOAA) Global Historical Climatology Network (GHCN) were used to construct annual and seasonal means. As the time span of the data included the recent recession and its aftermath, dummies were included for interviews from December 2007 through December 2010. Table 1 provides the definition and descriptive statistics of variables used in the model.

Results and Discussion

Regression Estimates

Estimates from truncated negative binomial models are presented in Table 2. We estimated the models with annual and seasonal climatic means, but the sign and magnitude of the coefficient was essentially the same in both models. Only seasonal models are presented because they slightly outperformed annual models based on Akaike Information Criterion (AIC). We also assumed that climatic effects were better captured with seasonal measures than annual measures because skiing is seasonal.

The coefficients on the travel cost variables (*TCOST*) were significant and negative for both wage rate assumptions. 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).

The negative sign for substitute distance (*SUBDIST*) appears counterintuitive 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; Loomis & McTernan, 2014). The relationship between demand and substitute price is expected to be positive in the case of perfect substitutes, but defining substitutes in recreation demand is difficult 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. Although these data are limited, they suggest that simple substitution variables, commonly used in travel cost modeling may be problematic given the complex nature of recreation behavior.

The coefficient on the household income proxy (*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). The negative coefficient of number of people traveling in the vehicle (*PEOPVEH*) suggests that the demand for skiing trips decreases with travel group size (Sardana et al., 2016). The result seems intuitive because trip planning

Table 1

Definition and Descriptive Statistics of Variables Used in Travel Cost Model of Demand for Downhill 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	0.35	637.63
TCOST2	Travel cost with opportunity cost based on 33% of wage	188.67	201.9	0.93	2697.29
ROCKY	Dummy variables, 1 if Rocky Mountain region, 0 otherwise	0.60	0.4	0	1
SUBDIST	One-way travel distance from origin to closest substitute site in miles	47.8	56.4	0.28	563.64
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	.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	0.30	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
ELEVATION	Elevation in meters	2063.2	756.8	105.0	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
SSNOWDEPTHSQR	Square of SSNOWDEPTH	2278.1	4291.5	0	26701.7
SRAIN	Seasonal average monthly rainfall(in millimeters) at the ski site in the study season	69.8	66.3	0	348.5

Table 2

Regression Estimates from Alternative Models of Downhill Skiing Demand at U.S. National Forests, by Alternative Assumption of Wage Rate (N=8,974)

Travel Cost and Socioeconomic 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*)
GENDER (1=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*)
SSNOWDEPTHSQR	-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

* indicates statistical significance at $\alpha = 0.05$ and numbers in parentheses are standard errors.

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 our no-wage model, holding other factors constant, predicted ski trips decline from age 20 up to an inflection point in the mid-40s, increasing thereafter through the relevant range of the data. The estimated coefficient for the *GENDER* binary variable (male=1) was positive and significant in both models corroborating the findings of Englin and Moeltner (2004).

The coefficient associated with number of people under 16 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 (Melstrom, 2014; Shrestha et al., 2002) which suggests that longer trip duration for recreation activities is correlated with fewer trips. However, Acharya et al. (2003) and Bowker et al. (1996) 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 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. 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 important because climatic factors vary with elevation. The negative coefficient on elevation suggests that skiers on sites of higher elevation are likely to take fewer trips than those visiting lower elevation sites. This result is perhaps counterintuitive because ski areas at higher elevations typically have more snow, lower temperature, and longer ski seasons (Scott, McBoyle, & Minogue 2007b). However, sites located at lower elevations are often more economically appealing, easier to access, and more appropriate for inexperienced skiers.

The climate factors in our models were significant and had the expected signs across both wage rate assumptions except for *SSNOWDEPTHSQR* in the 33% wage rate model. 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 (Englin & Moeltner, 2004; Hamilton et al., 2007; Loomis & Crespi, 1999; Shih et al., 2009). 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 has a positive impact on ski demand in the long run, but a negative impact 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. Many other studies reported a positive relationship between skiing demand and snow depth (Englin & Moeltner, 2004; Falk, 2013; Hamilton et al., 2007; Shih et al., 2009; Töglhofer et al., 2011).The negative and significant coefficient on rainfall (SRAIN) 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.

Economic Welfare Estimates

The economic value of downhill skiing trips in terms of CS per trip per person was derived by taking negative inverse of coefficient of travel cost variable in Table 2 and dividing by mean number of people in the traveling groups (*PEOPVEH* = 2.59). Table 3 presents the CS estimates along with 95% confidence intervals calculated through bootstrapping the standard errors (Martinez-Espineira & Amoako-Tuffour, 2008). With no opportunity cost of time assumed, the estimated CS per person per trip 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 CS per person per trip value of $98 ($63, $136). They also estimated CS per person snowboarding trip of $47 ($42, $53). The NVUM survey did not separate the observations for downhill skiers and snowboarders; therefore, we could not separately estimate models for these activities.

Table 3

Consumer Surplus per Trip per Person for Downhill 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)

95% confidence intervals are in parentheses.

Despite data limitations with NVUM round 1, Bowker et al. (2009) estimated the economic 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) estimated 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 integer nature of the data.

National Economic Benefits Estimation

We used per person per trip CS from Table 3 and NVUM annual visits estimation of downhill skiing (USDA Forest Service, 2017) 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 151.21 million, 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 our results, 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 data, they utilized a zonal TCM which is susceptible to aggregation bias (Moeltner, 2003) and considered less precise. Additionally, the PARVS data used are 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.

Our 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 our study showed substantial economic value, the CS estimates could be conservative. First, only the observations with one-way driving distance of less than 1,000 miles were analyzed as we trimmed data from long distance and international travelers. Second, we assessed value accruing only to those who listed downhill skiing as the primary purpose for their trip. Thus, side trips while on business or visiting family were not included, nor were trips where skiing was an ancillary activity.

Alternatively, it could be argued that our per-trip CS estimates are over-estimated because of measurement error problem in our construction of travel costs. Such error occurs when factors comprising the constructed travel cost, e.g., wage rate, mileage rate, lift tickets are measured with error; a problem endemic to nearly all travel cost applications in one form or another. Regression attenuation bias resulting from covariate measurement error can negatively bias coefficient estimates (Parresol et al., 2017). In count models, where the CS per trip estimate is the negative inverse of the travel cost coefficient, 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.

Changes in Welfare Due to Climate Change

Table 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.

Table 4

Predicted Change in Annual Visits and Welfare Impact under Climate Change Scenario through 2060 in U.S. National Forests

Model	Predicted individual visits in 2016	Predicted individual visits in 2060	Predicted aggregate visits decline 2016 to 2060 (millions)	NVUM TCM Based Loss in CS (millions)	Benefit Transfer Based Loss in CS (millions)
No wage rate	13.33	12.27	1.88	$171.57	$111.24
33% wage rate	13.24	12.11	2.02	$374.36	$119.39

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. We assumed that percentage decrease in annual visits on national forests would be at the same rate as the decrease in individual's visits. Following Eq. 2, we calculated the changes in welfare in 2060 attributable to climate change. 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 4).

An alternative approach, acknowledging the potential danger of downward bias in the travel cost model coefficients, is to combine our trip predictions with alternative CS estimates in a simple benefit transfer approach. Averaging across studies (Bergstrom & Cordell, 1991; Bowker et al., 2009; Cicchetti et al., 1976; Englin & Moeltner, 2004; Loomis & Crespi 1999; Morey, 1984; Morey, 1985; Rosenberger & Loomis, 2001; Walsh & Davitt, 1983; Walsh et al., 1983), 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 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 level 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 increases in ski participation. It is important to note that 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.

The projected change in climate variables could affect the quality of snow conditions in ski areas, resulting in decreased skiing participation. Our 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.

Summary and Conclusions

We estimated the net economic benefit of skiing on the national forest system, and assessed the likely effect of climatic factors on skiing demand and the aggregate economic value of downhill skiing. 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 our 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. Our 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 our estimates of consumer surplus. A more conservative estimate of the loss in welfare, ranging from $111 to $119 million, is obtained coupling our 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. It should be noted that 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, our constructed travel cost variable will lead to a downward bias in the relevant parameter estimate, the magnitude of which is difficult to estimate, and lead to an overestimate of consumer surplus from our truncated negative binomial model. To offset this likely bias, we used relatively conservative mileage costs, 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 our 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 underestimation of coefficient and standard errors and thus affect hypothesis testing. Insofar as this generated variable allowed us to increase the sample by more than 200%, and because we were not specifically calculating or testing any policy issues related to income elasticity, we considered the trade-off reasonable. Lastly, our 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.

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