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# Testing for Differential Effects of Forest Fires on Hiking and Mountain Biking Demand and Benefits

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Surveys of visitors to National Forests in Colorado were conducted to determine whether different fire ages and presence of crown fires have different effects on hiking and mountain biking recreation visits and benefits. Actual and intended behavior data were combined using a count-data travel cost model. The intended behavior trip questions asked about changes in number of trips due to the presence of a high-intensity crown fire, prescribed fire, and a 20-year-old high-intensity fire at the area respondents were visiting. Using the estimated recreation demand function, years since a non-crown fire had a statistically significant positive effect on the trip demand of hikers. In contrast, presence of crown fires had no statistically significant effect on the quantity of hiker trips, but had a significant and negative effect on mountain biking trips. Crown fires also had a large effect on the value per trip, with crown fires increasing the value per hiking trip but lowering the value per mountain biking trip.

*Key words:* consumer surplus, fire, mountain biking, recreation demand, travel cost method

## Introduction

The growing societal awareness of maintaining forest health and the rising costs of federal and state fire fighting are forcing public agencies to incorporate the economic values of nonmarketed resources into their fire management planning and decisions (González-Cabán). However, estimating the economic consequences is a difficult problem for fire managers because of a lack of information on the effects of fire on nonmarket uses such as recreation. Yet, recreation is one of the dominant multiple uses in the intermountain West.

While users of the U.S. Department of Agriculture (USDA) Forest Service National Fire Management and Analysis System use the Resources Planning Act (RPA) values for hiking, these values do not include values for mountain biking. Mountain biking has become a very popular activity on many National Forests, but to date only one valuation

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study on mountain biking has been published (refer to Fix and Loomis), and it does not apply to National Forests.

In addition, managers do not have a solid empirical basis for determining how hiking and mountain biking use changes immediately after fire and over the recovery interval. Based on their 1985 review of studies analyzing changes in recreation values after fire, Flowers et al. reported, "The studies demonstrate that no clear consensus has been reached on the duration for which fire effects on recreation should be measured or valued. The duration effects ranged from 6 months to 7 years among the studies.... The choice of duration is subjective and somewhat arbitrary because research on the question is scant" (p. 2).

Englin (1997) noted in his recent review of the literature on the effects of fire on recreation, "At present there are few studies quantifying the impacts of fire on the non-timber values produced by forests" (p. 16). The few published recreation demand studies on the effects of fire on recreation value focus on canoe trips in Nopiming Provincial Park in Manitoba, Canada (Englin et al.; Boxall, Watson, and Englin). These studies employ a travel cost framework and estimate a random utility model of canoe route choice in the face of a 10-year-old fire versus old growth forest. The loss in trip value varied between $15 and $22 with a fire in this canoe area (Englin 1997). Building on the two earlier studies, Englin (1997) constructs a simple time profile of value per trip as a function of years since a fire. Value per trip increases up to 60 years after the fire and then levels off in the jack pine forest.

Our analysis seeks to fill the gap in the published literature by reporting empirical estimates of how hiking and mountain biking use and benefits change over time from an initial forest fire, and by identifying whether the fire was a crown fire (i.e., a fire that burns to the tops of the trees).

## Research Design

### *Demand Estimating Method*

To estimate the effects of fire on recreation demand, this research combines data on actual number of trips taken by visitors to locations on National Forests unaffected and affected by fire with contingent visitation for alternative fire situations. The travel cost method (TCM) is used to estimate the recreation demand function. This method is based on the premise that even when there is no entry fee to use a public recreation site, recreationists pay an "implicit price" for the site's attributes or services when they travel to the site. The implicit price includes vehicle-related costs and time costs of the trip. If visitors are coming from different distances to a particular site and if there is variation in the number of trips they take, a demand function for the number of trips can be estimated (Loomis and Walsh). The demand curve can then be used to estimate visitors' willingness to pay net of travel costs or their consumer surplus.

Seasonal trips with actual fire conditions and the three fire scenarios are regressed on travel cost to the site, characteristics of the visitors, and attributes of the recreation area, including years since last fire and presence of a crown fire.

Using the travel cost method, the demand function is specified as:

$$Trips = (Travel\ Costs, Demographics, Income, Time\ Budget, Fire\ Characteristics, Trail\ Characteristics). \quad (1)$$

Trip costs include the variable costs of traveling to the site, such as the costs of gasoline and travel time. It has long been recognized that omission of travel time will bias the travel cost coefficient (Cesario). However, the means by which travel time should be incorporated into the TCM continues to be a lively area of research. Two main schools of thought exist on the appropriate procedure: (*a*) estimate the shadow price of time and add it to the travel cost variable, or (*b*) include travel time as a separate variable.

Shaw and Feather summarize the numerous consumer demand and labor supply models that are consistent with including travel time and the visitors' total recreation time budget as separate variables in the recreation demand function (see also Larson; Bockstael, Strand, and Hanemann). Because most individuals work a fixed number of hours (e.g., 40 hours a week) and cannot trade time for money by adjusting hours worked, Bockstael, Strand, and Hanemann suggest travel time be included as a separate variable along with total time budget. Individuals maximize utility subject to both a money income constraint and a time budget constraint due to their inability to freely substitute labor and leisure using the wage rate as a shadow price.

However, because of the usual multicollinearity between travel cost and travel time, it can be difficult to efficiently estimate separate coefficients on both variables. Consistent with transportation planning literature in the early 1970s, travel time can be multiplied by the wage rate or some fraction of the wage rate, often between 0.25 and 0.50 based on Cesario's review of the transportation literature and substantiated in the recreation literature by Englin and Shonkwiler. This dollar amount of travel time is then added to the transportation cost to arrive at the full trip price. Implicitly, this approach assumes an individual can trade money and travel time.

In our wage-shadow price model specification, the trip cost is the transportation costs—gas cost plus other vehicle expenses—plus the value of travel time at one-third the wage rate; a separate travel time variable is dropped. We report separate regression results for hikers and bikers using both treatments of travel time to evaluate the sensitivity of our hypothesis tests regarding fire effects to the different approaches to incorporating travel time.

Because trips per person per year to the site are represented by a nonnegative integer, a count-data regression model such as the Poisson is statistically appropriate as it limits the assignment of probabilities to just these outcomes (Creel and Loomis; Englin and Shonkwiler). In order to sample visitors to National Forest sites which had and had not experienced fire, it was cheaper to sample on-site. However, intercepting visitors on-site runs the risk of oversampling more avid users. Technically, this is known as endogenous stratification. Englin and Shonkwiler provide a straightforward correction for this problem in the Poisson count-data model. Their correction is adopted in our study.

### *Modeling Forest Fire Effects in TCM*

One way to test whether there is a significant difference in the response of hikers and mountain bikers to forest fires is to pool data on both types of visitors and use intercept shifters and slope interaction terms to test for differences between the two activities in terms of value per day and visitation reaction to fire. Equation (2) gives our pooled model in which the recreation activity, price, and fire effects variables interact. This model allows for a direct test of differences via significance of the activity interaction terms. The pooled model is specified as follows:

$$(2)\quad TRIPS_{ik} = \exp\big(B_0 + B_1(BIKE_i) + B_2(TC_{ik}) + B_3(TRTIME_{ik}) + B_4(INCOME_i) + B_5(TTBUD_i) + B_6(GENDER_i) + B_7(AGE_i) + B_8(HYPACT) + B_9(ELEVATION_k) + B_{10}(LP_k) + B_{11}(DRTRD_k) + B_{12}(FAGE) + B_{13}(CROWN) + B_{14}(BKTCOST_{ik}) + B_{15}(BKFAGE) + B_{16}(BKCFIRE) + B_{17}(TCFAGE) + B_{18}(TCCROWN) + B_{19}(BKTCFAGE) + B_{20}(BKTCCROWN) + B_{21}(CROWNFAGE) + B_{22}(BKCROWNFAGE)\big),$$

where all variables are defined in table 1, subscript $i$ represents individual respondents, and subscript $k$ denotes the particular site.

### *Calculation of Consumer Surplus per Day*

Consumer surplus is found by integrating the demand function over the relevant price range, which yields seasonal consumer surplus. Given that the Poisson count-data model is equivalent to a semi-log demand function, in general, the per trip consumer surplus is simply $1/B_2$ (Creel and Loomis). In the pooled model we must include the travel cost slope interaction for mountain biking (*BKTCOST*), so the consumer surplus per trip for mountain biking is written as:

$$(3)\qquad CS_{BIKE} = 1/(B_2 + B_{14}).$$

If the coefficient of *TCFAGE* is statistically significant, then fire age has an effect on the price slope of the demand curve (e.g., $B_{17} \neq 0$ in the pooled model). In this case, the consumer surplus per day will vary with years since the fire. The consumer surplus in any year $t$ for hikers is calculated by equation (4), and by equation (5) for mountain bikers:

$$(4)\qquad CS_{HIKE} = 1/(B_2 + B_{17} * FAGE)$$

and

$$(5)\qquad CS_{BIKE} = 1/((B_2 + B_{14} + B_{17} * FAGE) + (B_{19} * BKTCFAGE)).$$

Equation (5) reflects differences in value per trip for mountain biking ($B_{14}$) and differential effects fire age may have on mountain bikers' value ($B_{19} * BKTCFAGE$).

### *Fire Hypotheses Tests*

The hypothesis that fire has no effect on recreation visitation and valuation can be tested using the interaction model in equation (2) as follows:

$$(6)\qquad H_o: B_{12}(FAGE) = 0 \text{ versus } H_a: B_{12}(FAGE) \neq 0,$$

$$(7)\qquad H_o: B_{13}(CROWN) = 0 \text{ versus } H_a: B_{13}(CROWN) \neq 0,$$

$$(8)\qquad H_o: B_{15}(BKFAGE) = 0 \text{ versus } H_a: B_{15}(BKFAGE) \neq 0,$$

$$(9)\qquad H_o: B_{16}(BKCFIRE) = 0 \text{ versus } H_a: B_{16}(BKCFIRE) \neq 0,$$

$$(10)\qquad H_o: B_{19}(BKTCFAGE) = 0 \text{ versus } H_a: B_{19}(BKTCFAGE) \neq 0,$$

**Table 1. Variable Names and Definitions**

| Variable | Definition |
|---|---|
| $TRIPS_{ik}$ | Number of actual or intended trips over the season |
| $BIKE_i$ | Dummy variable where 1 = mountain biking, 0 = hiking |
| $TC_{ik}$ | Individual's share of reported travel costs (gas and other vehicle costs) |
| $TRTIME_{ik}$ | Individual's travel time to the site |
| $INCOME_i$ | Household income of the survey respondent |
| $TTBUD_i$ | Total time budget available for nonwinter recreation (weekends plus paid vacation) |
| $GENDER_i$ | Dummy variable where 1 = male, 0 = female |
| $AGE_i$ | Respondent's age |
| *HYPACT* | Dummy variable where 1 = trips in response to the contingent scenario, 0 = actual trips taken |
| $ELEVATION_k$ | Trailhead elevation above sea level |
| $LP_k$ | Dummy variable where 1 = lodgepole pine, 0 = otherwise |
| $DRTRD_k$ | Dummy variable where 1 = dirt access road, 0 = paved road |
| *FAGE* | The negative of how old the fire was at recreation area: -1 = one-year-old fire, -20 = 20-year old fire |
| *CROWN* | Dummy variable where 1 = crown fire, 0 = otherwise |
| *BKTCOST* | Interaction term of mountain biking (*BIKE*) and trip costs (*TC*), to test whether biking and hiking have different values per trip |
| *BKFAGE* | Interaction term of mountain biking (*BIKE*) and fire age (*FAGE*) to test whether bikers' visitation rate because of fire age is different from that of hikers |
| *BKCFIRE* | Interaction term of mountain biking (*BIKE*) and crown fire (*CROWN*) to test whether bikers' visitation rate because of crown fires is different from that of hikers |
| *TCFAGE* | Interaction term of trip cost (*TC*) and fire age (*FAGE*) to test for per trip value changes with the age of the fire |
| *TCCROWN* | Interaction term of trip cost (*TC*) and crown fire (*CROWN*) to test whether value per trip changes with a crown fire |
| *BKTCFAGE* | Interaction term of mountain biking (*BIKE*), trip cost (*TC*), and fire age (*FAGE*) to test whether the change in value per trip because of fire age is the same for bikers as for hikers |
| *BKTCCROWN* | Interaction term of mountain biking (*BIKE*), trip cost (*TC*), and crown fire (*CROWN*) to test whether the change in value per trip because of a crown fire is the same for bikers as for hikers |
| *CROWNFAGE* | Interaction of crown fire (*CROWN*) with fire age (*FAGE*) |
| *BKCROWN* * *FAGE* | Interaction of mountain biking (*BIKE*) with crown fire (*CROWN*) multiplied by fire age (*FAGE*) |

(11) $H_o$: $B_{20}(BKTCCROWN) = 0$ versus $H_a$: $B_{20}(BKTCCROWN) \neq 0$,

(12) $H_o$: $B_{21}(CROWNFAGE) = 0$ versus $H_a$: $B_{21}(CROWNFAGE) \neq 0$,

(13) $H_o$: $B_{22}(BKCROWNFAGE) = 0$ versus $H_a$: $B_{22}(BKCROWNFAGE) \neq 0$.

These null hypotheses can be tested individually using *t*-tests on the individual coefficients.

*Likelihood-Ratio Test Model*

Even without interaction terms for every variable in equation (2), the inclusion of a large number of interaction terms increases the likelihood of multicollinearity. To reduce the potential for multicollinearity and to allow all of the coefficients to take on different values for hikers and mountain bikers, separate models are estimated [equation (14)]:

$$(14)\quad TRIPS = \exp\big(B_0 + B_1(TC) + B_2(TRTIME) + B_3(INCOME) + B_4(TTBUD) + B_5(GENDER) + B_6(AGE) + B_7(HYPACT) + B_8(ELEVATION) + B_9(LP) + B_{10}(DRTRD) + B_{11}(FAGE) + B_{12}(CROWN) + B_{13}(TCFAGE) + B_{14}(TCCROWN) + B_{15}(CROWNFAGE)\big).$$

The null hypothesis of coefficient equality is tested using the likelihood-ratio test. The null hypothesis is given by equations (15a) and (15b):

$$(15a)\quad H_o: B_{HIKE} = B_{BIKE},$$

$$(15b)\quad H_a: B_{HIKE} \neq B_{HIKE}.$$

The likelihood-ratio test determines if there is a significant reduction in the likelihood function when two separate equations are estimated (i.e., the unrestricted models) as compared to one pooled equation (i.e., the restricted model which imposes coefficient equality). If the null hypothesis is true, there will be little difference between the sum of the two separate log-likelihood functions and the log-likelihood value for the pooled model. The test statistic is distributed chi-squared.

*Evaluating the Effect of Fire on Visitor Use and Benefits*

Using the demand equations, the effect of fire age or crown fires on the number of trips and value per day of the recreation activity can be calculated. For example, we can calculate the effect of a recent fire (year zero) versus older fires (year −20 or −50) on hiker and mountain biker use and benefits from National Forests in Colorado.

## Data Collection

*Overall Sample Design*

National Forests were selected for the study sites, and visitors were intercepted at trailhead locations. Trailheads were stratified by acres burned and year of fire. Thus, the main strata were fires of size D (100–299 acres), E (300–999 acres), F (1,000–4,999 acres), and G (5,000+ acres). The years were grouped into fire ages, with zero equal to the year of the survey (1998) and counting back from then (e.g., 1–2, 3–6, 7–10, 11–20, 21–29, and 30+), dating the earliest fires at 1970. Equivalent unburned sites were sampled at each of the National Forests to provide a control and represent the oldest age category.

Three National Forests in Colorado were selected in order to provide a sample of the possible combinations of fire age and acres burned: the Arapaho-Roosevelt, Gunnison-Uncompaghre, and Pike-San Isabel National Forests. Our sample includes two front-range National Forests and one interior National Forest. We believe we can generalize from the forest sites sampled within a strata to the other forests within that same strata. Specifically, the results for strata sampled in the Arapaho-Roosevelt, Gunnison-Uncompaghre, and Pike-San Isabel National Forests may be indicative of results for similar strata in Rocky Mountain Region forests not sampled. For example, many of the Arapaho-Roosevelt fires were similar in size and date to fires on other National Forests.

We sampled 35 days during the main summer recreation season. A total of 10 sites across the three National Forests were sampled. This schedule generally allowed one sampling rotation of two days (one weekday and one weekend day) at nearly all recreation sites during July and August of 1998.

### *Survey Protocol*

The interviewer stopped individuals as they returned to their cars at the respective National Forest parking area. The interviewer introduced himself, identified his university affiliation, and provided a statement of purpose. Then the interviewer gave a survey packet to all individuals in the group 16 years of age and older. The interviewer indicated the survey could be completed at home and mailed back in a postage-paid return envelope that was enclosed in the packet.

### *Survey Structure*

In the first section of the survey, recreation users were asked to check off their primary or main recreation activity. Next, they were asked their travel time and travel distance to the site. Questions about their travel costs followed. Respondents were then asked the number of trips they had made to the site so far this year, and the number of planned trips to the site during the remainder of the year. In addition, respondents were asked how these trips would change if their trip costs increased.

The next portion of the survey presented the following three fire scenarios:

- One-half of the trail experienced a recent high-intensity crown fire. This scenario was depicted with a color photo of standing blackened trees that had no needles. The photo was taken from the Buffalo Creek fire which had occurred two years earlier.

- One-half of the trail experienced a light (prescribed) burn. The photo illustration showed the lower trunk and lower branches of the trees burned; there were reddish colored needles on these lower branches, but the tops of the trees were green and there were numerous other green trees present.

- One-half of the trail reflected an old (20 years) high-intensity fire. The photo for this scenario had standing dead trees with white tree trunks, downed trees, and younger, newer, green trees.

For each scenario, visitors were asked how their trips to the site where they were intercepted would change if half the trail were as depicted in each photo. The advantage of the fire effects scenarios in the stated preference portion of the survey is that the impacts of a wide range of fires on forest conditions could be conveyed to each visitor. These photos allowed us to determine the effect of high-intensity crown fires, prescribed fires, and older fires on recreation use.

A fourth contingent behavior question used increases in trip costs ($3, $7, $9, $12, $15, $19, $25, $30, $35, $40, and $70) to elicit how trips to the recreationist's current site would change if travel costs increased. Responses to this question provided additional price variability to supplement the actual variability in travel costs due to differences in residential locations relative to the recreation sites. In total, four of the fire observations from each visitor involved contingent behavior responses.

The surveys were pretested at two of the National Forests. Individuals were asked to fill out the survey and provide any comments or feedback. A few questions were clarified as a result of comments received during the pretests.

### *Inclusion of Additional Site Characteristics*

To isolate the effects fire may have on recreation visitation, it is important to control for other related site attributes. The candidate measures of site attributes included those that have been significant in past forest recreation studies (Englin et al.). Thus, several site characteristics, such as elevation above sea level and presence of a dirt road, were chosen on this basis. Fire attributes included the fire age and intensity. These data were obtained from the USDA Forest Service Kansas City fire analysis statistics (KFAS) system and verified with the district offices. By the sample design, there was a range of small to large fires, and low-intensity prescribed fires to high-intensity fires. There was also a range of ages of fires, although most were fairly recent. Trails from four trailheads had experienced recent fires, one trailhead had an old fire, and five had no visible fire effects. Data on dominant forest type were also used to test for any differences in response by forest type.

## Results

### *Survey Returns*

Out of 541 recreationists contacted, only 14 refused to participate in our survey. A total of 527 surveys were handed out. Of these, 354 were returned after the reminder postcard and second mailing to nonrespondents, for an overall response rate of 67%.

### *Descriptive Statistics*

Most visitors sampled at the trailheads were hiking (59%) or mountain biking (30%). The remainder of visitors (11%) were horseback riding or on motorized vehicles, and were not included in this analysis. The average visitor was on-site for five hours, drove 77 miles (one way), and incurred gasoline costs of $12 (for a cost per round-trip mile of 7.8 cents). Hikers drove nearly twice as far as mountain bikers.

Based on the demographics of the sample, 56% of total respondents were male. Of the mountain biker respondents, however, more than 60% were male. The average respondent was 36.5 years old, with an education level of 16.3 years. More than 90% of our sample worked outside the home and visited the recreation site on weekends, holidays, or paid vacation. The average household size was 2.54 people, and the typical household earned \$67,232 annually.

### *Econometric Analysis*

Table 2 reports the econometric results for the pooled model in equation (2).[1] *BIKE* is significant and negative, indicating mountain bikers take significantly fewer trips than hikers. Travel cost (*TC*) and travel time (*TRTIME*) are statistically significant ($p < 0.01$). Total time available for recreation (*TTBUD*) has a significant positive effect on number of trips, as does *GENDER* (males take significantly more trips than females). The significance of the *HYPACT* dummy variable indicates a positive hypothetical bias to the number of trips for a given contingent behavior scenario as compared to the number of actual trips taken in the same circumstances.

In terms of site characteristics, presence of lodgepole pine (as compared to aspen and Douglas fir) reduced visitation, as did having to drive on a dirt road to reach the trailhead. The model has some multicollinearity due in part to the interaction terms, and in part due to natural correlations such as the presence of lodgepole pine occurring primarily at higher elevations ($r = 0.52$) and dirt roads being more prevalent at higher elevations ($r = 0.59$).

Travel cost demand models were also estimated separately for hiking and mountain biking (tables 3A and 3B). For both of these activities, the travel cost coefficients are statistically significant, whether estimated using travel cost and travel time as separate variables or when combining travel cost and the value of travel time into one variable. The travel time coefficient is negative and significant for hikers, but positive and slightly significant for mountain bikers in the models including a separate travel time variable. While income and time budget coefficients are significant in all models, they have the opposite signs for mountain bikers and hikers. Income is consistently positive for mountain bikers, and consistently negative for hikers, while the reverse is true for total time budget. Perhaps the expense (\$500 to \$2,500) of good mountain bikes makes mountain biking more of a normal good, while hiking's parsimonious equipment requirements makes it more an inferior good.

The hypothetical versus actual dummy variable *HYPACT* is statistically significant and positive for hikers in both models (table 3A), indicating hikers did tend to overstate the number of hiking trips in the contingent behavior scenarios. However, *HYPACT* is insignificant in both mountain biker models (table 3B), suggesting there is no difference in stated versus actual mountain biking trips. The presence of lodgepole pine (relative to aspen and Douglas fir) and dirt roads remain negative factors as in the pooled interaction model, while elevation above sea level is a positive factor in all models. (Results of forest fire variables are discussed in the hypothesis testing section.)

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[1] Englin and Shonkwiler prove that a direct approach for correcting endogenous stratification in a Poisson count-data model is to subtract one from each person's reported number of trips. This works well for revealed preference observations collected on-site (since the number of trips is at least one) and for most contingent behavior scenario trip responses. However, some individuals reported zero trips with one or more of the contingent behavior scenarios. These zero trip observations cannot be adjusted for endogenous stratification using the Englin and Shonkwiler approach as it would yield negative trip values, something not allowed in a count-data model.

**Table 2. Regression Results: Pooled (Mountain Bikers and Hikers) Interactive TCM Model (N = 853)**

| Variable | Coefficient | *t*-Statistic | Probability |
|---|---|---|---|
| Constant | -3.402 | -15.492 | 0.000 |
| *BIKE* | -0.575 | -4.983 | 0.000 |
| *TC* | -0.035 | -4.653 | 0.000 |
| *TRTIME* | -0.003 | -5.232 | 0.000 |
| *TTBUD* | 0.013 | 18.360 | 0.000 |
| *INCOME* | -1.27E-06 | -2.339 | 0.019 |
| *GENDER* | 0.887 | 15.363 | 0.000 |
| *AGE* | 0.008 | 3.297 | 0.001 |
| *HYPACT* | 0.299 | 2.951 | 0.003 |
| *LP* | -1.854 | -17.158 | 0.000 |
| *DRTRD* | -1.877 | -14.040 | 0.000 |
| *ELEVATION* | 0.0005 | 13.544 | 0.000 |
| *CROWN* | -0.031 | -0.315 | 0.753 |
| *FAGE* | -0.017 | -6.210 | 0.000 |
| *BKTCOST* | 0.024 | 2.578 | 0.009 |
| *BKFAGE* | 0.015 | 4.938 | 0.000 |
| *BKCFIRE* | -0.730 | -3.960 | 0.000 |
| *BKTCCROWN* | -0.019 | -1.828 | 0.067 |
| *BKTCFAGE* | -0.0003 | -1.198 | 0.230 |
| *TCCROWN* | 0.026 | 3.077 | 0.002 |
| *TCFAGE* | 0.0004 | 2.027 | 0.042 |
| *CROWNFAGE* | 0.015 | 2.884 | 0.004 |
| *BKCROWNFAGE* | -0.041 | -4.193 | 0.000 |

| | |
|---|---|
| $R^2$ | = 0.61 |
| Adjusted $R^2$ | = 0.60 |
| Mean of dependent variable | = 2.71 |
| Std. error of regression | = 6.13 |
| Log likelihood | = -2,997.19 |
| Restricted log likelihood | = -4,831.86 |
| Likelihood-ratio statistic (22 df) | = 3,669.33 |
| Probability (likelihood-ratio statistic) | = 0.00 |

### *Consumer Surplus Estimates*

Using the travel cost coefficients in table 3A, the consumer surplus for hiking is $34 per trip in the initial year of a non-crown fire (*FAGE* = 0 and *CROWN* = 0) with the model treating travel cost and value of travel time as separate variables, and $111 per trip in the model with travel cost and value of travel time combined. This is a surprising sensitivity to how travel time is treated in these two models. However, because numerous studies have been conducted to value hiking, we can compare our values to past estimates.

**Table 3A. Regression Results: Separate Hiking TCM Demand Model**

| | Separate TC and Travel Time | | Combined TC and Travel Time | |
|---|---|---|---|---|
| Variable | Coefficient | *t*-Statistic | Coefficient | *t*-Statistic |
| Constant | -2.5477*** | -10.95 | -2.918*** | -12.73 |
| *TC* | -0.0293*** | -4.29 | -0.009*** | -2.67 |
| *TRTIME* | -0.0011** | -2.39 | N/A | |
| *INCOME* | -9.0E-06*** | -13.10 | -8.0E-06*** | -11.09 |
| *TTBUD* | 0.0199*** | 21.72 | 0.012*** | 21.69 |
| *GENDER* | 0.8916*** | 13.25 | 0.900*** | 13.36 |
| *AGE* | -0.0129*** | -3.80 | -0.127*** | -3.81 |
| *HYPACT* | 0.5383*** | 4.42 | 0.634*** | 5.23 |
| *LP* | -1.7796*** | -14.85 | -1.813*** | -15.24 |
| *DRTRD* | -1.3747*** | -8.59 | -1.444*** | -8.97 |
| *ELEVATION* | 0.0003*** | 9.73 | 0.0003*** | 10.16 |
| *FAGE* | -0.0205*** | -6.78 | -0.023*** | -7.74 |
| *CROWN* | 0.0181 | 0.19 | 0.155 | 1.59 |
| *TCFAGE* | 0.0002 | 1.24 | 0.0002*** | 2.78 |
| *TCCROWN* | 0.0224*** | 2.98 | -0.0007 | -0.02 |
| *CROWNFAGE* | 0.0215*** | 3.94 | 0.023*** | 4.27 |
| Mean of dependent variable | = 3.14 | | = 3.14 | |
| Adjusted $R^2$ | = 0.73 | | = 0.72 | |
| Std. error of regression | = 6.05 | | = 6.13 | |
| Log likelihood | = -1,936 | | = -1,968 | |
| Restricted log likelihood | = -3,724 | | = -3,721 | |
| Likelihood-ratio statistic (15 df) | = 3,575 | | = 3,506 | |
| Prob. (likelihood-ratio statistic) | = 0.00 | | = 0.00 | |
| N | = 545 | | = 544 | |

Note: Double and triple asterisks (*) denote statistical significance at the .05 and .01 levels, respectively.

Walsh, Johnson, and McKean estimate a national average value of hiking of $29; Rosenberger and Loomis updated that study, finding a hiking value of $37 for the Rocky Mountains. Thus, the value per trip with travel cost and travel time as separate variables is more consistent with the values in the literature than are values from the model which combines the value of travel time with the travel cost variable.

Using the mountain biking demand function in table 3B, the consumer surplus per trip for mountain bikers in the initial year of the non-crown fire (*FAGE* = 0 and *CROWN* = 0) ranges from $33 per day in the travel cost combined with travel time model to $30 per day in the travel cost and travel time separate model. The initial year of a crown fire (*FAGE* = 0 and *CROWN* = 1) yields a value of $62 per trip for the model with travel cost and travel time as separate variables.

### *Results of Fire-Effects Hypotheses*

*Crown Fires.* In the pooled model (table 2), the dummy variable for crown fire was insignificant, just as it is in the separately estimated hiking models (table 3A). However,

**Table 3B. Regression Results: Separate Mountain Biking TCM Demand Model**

| | Separate TC and Travel Time | | Combined TC and Travel Time | |
|---|---|---|---|---|
| Variable | Coefficient | *t*-Statistic | Coefficient | *t*-Statistic |
| Constant | -4.227*** | -6.39 | -3.132*** | -5.14 |
| *TC* | -0.033*** | -2.99 | -0.030*** | -4.73 |
| *TRTIME* | 0.004** | 1.94 | N/A | |
| *INCOME* | 1.8E-05*** | 20.56 | 2.1E-05*** | 20.82 |
| *TTBUD* | -0.027*** | -7.50 | -0.031*** | -7.42 |
| *GENDER* | 0.146 | 1.15 | 0.124 | 0.98 |
| *AGE* | 0.059*** | 13.98 | 0.057*** | 15.45 |
| *HYPACT* | -0.092 | -0.47 | -0.093 | -0.48 |
| *LP* | -3.460*** | -10.17 | -3.452*** | -10.33 |
| *DRTRD* | -3.202*** | -11.11 | -2.916*** | -10.63 |
| *ELEVATION* | 0.0004*** | 5.63 | 0.0004*** | 5.07 |
| *FAGE* | 0.003 | 0.57 | 0.006 | 1.14 |
| *CROWN* | -0.767*** | -4.45 | -0.788*** | -4.04 |
| *TCFAGE* | -1.5E-05 | -0.06 | -0.0001 | -1.01 |
| *TCCROWN* | 0.012 | 1.10 | 0.005 | 0.71 |
| *CROWNFAGE* | -0.032*** | -3.31 | -0.034*** | -3.45 |
| Mean of dependent variable | = 1.95 | | = 1.95 | |
| Adjusted $R^2$ | = 0.64 | | = 0.66 | |
| Std. error of regression | = 2.85 | | = 2.77 | |
| Log likelihood | = -609.63 | | = -606.60 | |
| Restricted log likelihood | = -1,053.18 | | = -1,053.18 | |
| Likelihood-ratio statistic (15 df) | = 887.09 | | = 893.17 | |
| Prob. (likelihood-ratio statistic) | = 0.00 | | = 0.00 | |
| N | = 308 | | = 308 | |

Note: Double and triple asterisks (*) denote statistical significance at the .05 and .01 levels, respectively.

*CROWN* was significantly a negative demand shifter for mountain bikers (table 3B). In the pooled interaction model (table 2), the price slope interaction with *CROWN* was significant, but this was generally not the case in the separately estimated models. However, the interaction of *CROWN* fire and fire age (*FAGE*) was statistically significant in the pooled interaction model (table 2), and the separately estimated hiking (table 3A) and mountain biking (table 3B) models. Note that the sign is reversed for the two activities, with areas having older crown fires reducing hiking use (as noted below, *FAGE* is coded as a negative number, denoting years from fire), and older crown fires increasing mountain biking trips over time. This pattern of visitor use and benefits with fire age becomes more evident in table 4.

*Fire Age.* In the pooled model (table 2), years since the fire (*FAGE*) was significant at the 0.01 level. The same is true of the price slope interaction term and fire age (*TCFAGE*), indicating the value per trip will also change with fire age. Hikers and mountain bikers also appear to react differently to fire age (i.e., *BKFAGE* is significantly different from zero in table 2). This is even more apparent in tables 3A and 3B, where the intercept shifter *FAGE* is negative and statistically significant for hikers, but positive and not significant for mountain bikers. While *FAGE* has a negative sign in table 2 and table 3A, its influence on hiker visitation is positive for non-crown fires because years since the fire is a negative number (i.e., counting backwards with a fire in the current year equaling zero, -10 for an area with a 10-year-old fire, and going to -50 for no visible fire effects). The same pattern of significance of *FAGE* for hikers and insignificance for mountain bikers occurs in the TCM models estimated using a price variable that combines the transportation cost and the shadow price of travel time. For mountain bikers, fire age only makes a significant change in trips when the forest fires are crown fires (again, this pattern becomes more evident in table 4).

The likelihood-ratio test of these individual models against an identically specified pooled model suggests we should reject the null hypothesis of equality of demand coefficients for mountain bikers and hikers in Colorado. The $\chi^2$ statistic is significant well beyond the 0.01 level for both the travel cost-travel time separate variable model and the combined travel cost and travel time model. This result is consistent with the findings of the pooled interaction model where the fire intercept term for bikers and the interaction terms for bikers, fire age, and crown fire were all statistically significant.

### *Effects of Forest Fire Type and Fire Age on Visitor Use and Benefits*

Table 4 presents the time path of use and benefits associated with years from an initial crown fire and non-crown fire for both mountain bikers and hikers using the separate hiker and biker models. We use the separate models because the likelihood-ratio tests strongly reject the pooled models. However, results for the pooled interaction model (table 2) are available from the first author. Given the similar forest fire coefficients between the TCM models with travel cost and travel time separate and combined using the value of travel time, the simulations are run just for the separate models to conserve space in the tables.

The effect of fire on recreation use over time depends on the recreation activity (i.e., hiking or biking) and whether the fire is a crown fire or is a non-crown fire (i.e., a ground fire or prescribed burn). Hikers take more trips (nearly four per year) to areas without non-crown fire (i.e., 50 years after fire), but hiking use decreases slightly over time in areas that have experienced crown fires (from 3.03 trips to 2.78 trips).

As seen from table 4, the consumer surplus per hiking trip drops far more rapidly than trips as crown fire age increases. Hiking through an area where a recent crown fire occurred is a relatively novel activity, and such areas typically experience a profusion of wildflowers. This combination is apparently worth a great deal of money to hikers. In contrast, hiking use increases over time as areas experiencing non-crown fires recover (from 2.65 trips to nearly four trips in 50 years). The average consumer surplus per trip decreases only slightly over the 50-year time interval (from $34 to $24), although not as substantially as with crown fires (from $145 to $55).

The opposite pattern is evident in table 4 for mountain bikers. They take significantly more trips over time in areas that either have had no crown fires or have largely recovered from crown fires (i.e., 50 years after the crown fire). Further, the value per trip changes substantially from $62 in the year of a crown fire, rising to $138 in the no-crown-fire condition. In areas with non-crown or ground fires, however, biking trips barely change over time (1.73 to 1.59 trips over the 50-year time period). The same is true of average trip value for bikers, which changes by only $1 (from $30 to $31 per trip).

**Table 4. Pattern of Visitor Use and Benefits with Fire Age**

| Description | | Year of Fire | Years After Fire 10 | 20 | 50 (no fire) |
|---|---|---|---|---|---|
| **HIKERS:** | ▸ **Crown Fires** | | | | |
| | Number of trips | 3.03 | 2.98 | 2.93 | 2.78 |
| | Value per trip | $145 | $109 | $87 | $55 |
| | ▸ **Non-Crown Fires** | | | | |
| | Number of trips | 2.65 | 2.84 | 3.05 | 3.97 |
| | Value per trip | $34 | $32 | $30 | $24 |
| **BIKERS:** | ▸ **Crown Fires** | | | | |
| | Number of trips | 1.29 | 1.47 | 1.71 | 3.00 |
| | Value per trip | $62 | $69 | $80 | $138 |
| | ▸ **Non-Crown Fires** | | | | |
| | Number of trips | 1.73 | 1.70 | 1.67 | 1.59 |
| | Value per trip | $30 | $30 | $31 | $31 |

A natural question arises as to what causes these different effects between hikers and mountain bikers. At present there is little published research on mountain bikers, and no studies focusing on mountain bikers' preferences for forested landscape vis-à-vis those of hikers. Discussions with other economists and mountain bikers suggested our initial hunch was reasonable: a possible reason crown fires have a large initial negative effect on mountain biking trips may be due in part to obstructions created by the large dead trees falling across the trail as a result of crown fires. In fact, one of the photos of the crown fire (included in the survey questionnaire) showed a large log on the ground.

While such obstacles may be inconvenient for hikers, they can often step over fallen logs. In contrast, most mountain bikers must dismount and lift their bikes over logs more than 6" in diameter, and even the best mountain bikers often cannot surmount downed logs of 12" or more. Their hiker counterparts are better able to traverse logs, and likely have chosen to move at a more leisurely pace to enjoy the wildflowers and novelty of a crown fire area.

If future research replicates our findings of adverse effects to mountain bikers, understanding the reasons why is an important area for interdisciplinary collaboration between economists and recreation specialists.

## Conclusions

Surveys of visitors to National Forests in Colorado were conducted to determine whether hikers and mountain bikers had distinct responses to the presence of crown fires or forest fires of different ages. Revealed and stated preference data were pooled to estimate a count-data travel cost method (TCM) demand curve.

We found that years since the most recent fire had a statistically significant and positive effect on the demand for hiking trips; hiking trips increased over a 50-year period after a non-crown fire. Hiking trips were less affected by the presence of a crown fire, but such fires did influence the value per trip. Crown fires had a significant adverse effect on mountain biking use and benefits. Non-crown fires had minimal effects on mountain biker trips or value per trip. The different effects of crown and non-crown fires may be related to the difficulty for mountain bikers posed by large downed trees from a crown fire. Bikers must dismount and carry their bikes over large logs that have fallen across the trail after a crown fire has passed through an area.

If our results are corroborated in future analyses, a management implication of this study would be that the U.S. Forest Service should continue to publicize the locations and recreation trails affected by a crown or high-intensity wildfire. Given the higher hiking value per trip and lower mountain biking value per trip immediately after a crown fire, these areas would be attractive to hikers, and mountain bikers could avoid them. Providing visitors this fire-related information would allow them to better satisfy their recreational preferences, and therefore would increase overall recreation benefits provided by a given National Forest.

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## References

Bockstael, N., I. Strand, and M. Hanemann. "Time and the Recreation Demand Model." *Amer. J. Agr. Econ.* 69,2(1987):293–302.

Boxall, P., D. Watson, and J. Englin. "Backcountry Recreationists' Valuation of Forest and Park Management Features in the Canadian Shield Region." *Can. J. Forest Res.* 26(1996):982–90.

Cesario, F. "Value of Time in Recreation Benefit Studies." *Land Econ.* 52,1(1979):32–41.

Creel, M., and J. Loomis. "Theoretical and Empirical Advantages of Truncated Count Data Estimators for Analysis of Deer Hunting in California." *Amer. J. Agr. Econ.* 72,2(1990):434–45.

Englin, J. "Review of the Existing Scientific Literature on the Effects of Fire on Recreation Use and Benefits." Staff pap., Dept. of Appl. Econ. and Statis., University of Nevada, Reno, 1997.

Englin, J., P. Boxall, K. Chakraborty, and K. Watson. "Valuing the Impacts of Forest Fires on Backcountry Forest Recreation." *Forest Sci.* 42(1996):450–55.

Englin, J., and J. S. Shonkwiler. "Estimating Social Welfare Using Count Data Models: An Application to Long-Run Recreation Demand Under Conditions of Endogenous Stratification and Truncation." *Rev. Econ. and Statis.* 77,1(1995):104–12.

Fix, P., and J. Loomis. "Comparing the Economic Value of Mountain Biking Estimated Using Revealed and Stated Preference." *J. Environ. Planning and Manage.* 41,2(1998):227–36.

Flowers, P., H. Vaux, P. Gardner, and T. Mills. "Changes in Recreation Values After Fire in the Rocky Mountains." Res. Note No. PSW-373, Pacific Southwest Forest and Range Exp. Sta., USDA/Forest Service, Albany CA, 1985. [15 pp.]

González-Cabán, A. "The Economic Impact of Fire on Forest Resources." *Wildfire* 1,1(1993):16–21.

Larson, D. "Joint Recreation Choices and Implied Values of Time." *Land Econ.* 69,3(1993):270–86.

Loomis, J., and R. Walsh. *Recreation Economic Decisions*, 2nd ed. State College PA: Venture Publishing, 1997.

Rosenberger, R., and J. Loomis. "Using META Analysis for Benefit Transfer." *Water Resour. Res.* 36,4(2000):1097–1107.

Shaw, W. D., and P. Feather. "Possibilities for Including the Opportunity Cost of Time in Recreation Demand Systems." *Land Econ.* 75,4(1999):592–602.

Walsh, R., D. Johnson, and J. McKean. "Benefit Transfer of Outdoor Recreation Demand Studies: 1968–1988." *Water Resour. Res.* 28,3(1992):707–13.