Use of Principal Component Attractiveness Indexes in Recreation Demand Functions

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The method of principal components is used to construct attractiveness indexes for existing and proposed wilderness areas in California. Rankings of areas based on this procedure are compared with those based on size and the subjective attractiveness index developed by the Forest Service. The derived indexes are then used to develop alternative opportunities variables that appear as explanatory variables in outdoor recreation demand functions. Results indicate that substantially better explanatory capacity can be achieved over alternative measures by including a competitive factor in the demand functions. The paper concludes by considering the substitution effects of introducing new wilderness areas into the system.

Recent legislative enactments and an increased public awareness about environmental concerns have led to the development of techniques for assessing scenic beauty in recreational areas. Legislation such as the National Environmental Policy Act of 1969 [P.L. 91-190] requires that scenic beauty and other indicators of recreational value be considered in forestry management decisions. In order to fulfill legislative mandate and to provide guidance in managing public lands, attractiveness measures have been developed to assess the scenic beauty of public forests and wildlands.

The very nature of scenic beauty makes commensurability of prime concern. In a recent annotated bibliography [Arthur and Boster], the 167 papers reviewed reveal a variety of procedures used by sociologists, psychologists, and economists to measure scenic beauty. While these measures of an area's characteristics may be useful to forest managers for predicting the aesthetic consequences of alternative land uses, economists have favored the indirect use of attractiveness indexes to measure landscape quality. For example, an important use of these indirect measures combines an area's accessibility and attractiveness factors to rank individual landscapes according to their "competitiveness" [Grubb and Goodwin, and Knetsch, 1963]. Since an alternative area's accessibility and attractiveness can account for the substitution effects on the demand for a site's services, an indirect attractiveness index can be used to estimate an area's recreation demand function.

This paper utilizes the method of principal components to construct attractiveness indexes for existing and proposed recreation areas in the United States. The derived index is incorporated into an alternative opportunities variable which appears as one of the explanatory variables in an outdoor recreation demand function. The model is tested on cross-sectional data obtained from permits issued by the Forest Service for wilderness area use in California in 1975. The results indicate that estimates of recreation demand based on principal components attractiveness measures can provide substantially better explanatory capacity than alternative measures.

In the first section, the construction of attractiveness indexes is explained and tested against other indexes currently available for

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measuring scenic beauty of the same wilderness areas. The second section describes the recreation demand function and justifies the socio-economic factors and the "alternative opportunities" variables used in the model. The final two sections summarize empirical results and explore implications of reliance on principal component attractiveness indexes to measure recreation demand.

Principal Component Indexes

The concept of principal component analysis essentially amounts to transforming a set of k variables with n observations on each into a new set of variables which will be pairwise uncorrelated and of which the first will have the maximum possible variance [Dhrymes or Johnston]. One application of prinicpal component analysis is index construction. That is, the collective behavior of a large number of variables can be represented by a smaller number of variables — typically one. This is the manner in which it is applied in this paper. Alternative attractiveness indexes are constructed from the scenic quality, access, and facilities characteristics given in Table 1 for the existing and proposed (study) wilderness areas in the California wilderness area system.[1] A large number of physical characteristics are represented by one principal component which accounts for a specified percentage of the total variance present in all of the variables.

Two principal component indexes for the wilderness areas are presented in Table 2. Wilderness areas are first ranked according to their size and then rankings based on the various indexes are compared to this ranking. Principal component index number one, P.C. (1), was based on the following variables: streams, peaks, lakes, trails, entry, perimeter, campground units, and forest.[2] The unit of measurement of each variable is given at the top of Table 1. The interpretation of each variable is obvious except for forest acreage. It includes all the soft and hardwood trees acreage. The index based on these variables accounts for 78 percent of the total variance of the eight characteristics. The ranking of wilderness areas according to this attractiveness index is given in column 4 of Table 2. The John Muir wilderness was ranked first in attractiveness, Salmon-Trinity Alps second, etc. In general, the index ranked wilderness areas in the same order as their size. However, differences do occur. For example, San Rafael is fourth according to area, but fifteenth according to the attractiveness index.

It appears the principal component index has weighted size of an area by various other characteristics to modify the rankings in order to take into account the other area characteristics. That is, areas with relatively less streams, peaks, lakes, trails, entry, perimeter, campground units, and forest in relation to their size do not appear to be ranked as high, if the only determinant for attractiveness was size. To determine if principal component index 1 ranked the areas differently in a statistically significant sense than that based on size, a Spearman rank correlation coefficient (rho) was computed [Siegel]. It is a measure of association between two variables that are measured in at least an ordinal scale. The value of the statistic, r_s, is 0.88 which is significant at the 0.01 level of significance.[3] This result indicates that P.C. (1) does not rank the areas significantly different from size on an ordinal scale.

[1]The term "attractiveness" is used in a generic sense in this paper including access as well as facilities characteristics.

[2]The principal component attractiveness index could be based on more than one principal component; however, to keep the index as simple as possible, only the first component was used in each index.

[3]For a sample size of ten or larger, the significance of an obtained r_s under the null hypothesis of no correlation may be tested by the following t statistic [Siegel, p. 212]

$$t = r_S \sqrt{(N-2)/(1-r_S^2)}$$

In this case N is 39.

Many of the characteristics employed in the construction of P.C. (1) are implicitly related to size; thus, an attempt was made to purge its influence on the other characteristics. This was done by dividing all the other characteristics by size. The second principal component index, P.C. (2), was based on the following variables: size, precipitation, streams, peaks, lakes, trails, entry, campground units, and forest, all expressed in per unit size except precipitation and, of course, the variable size itself.[4] This index, composed of nine characteristics, accounts for 28 percent of the total variance of the variables. Thus, the amount of total variability explained by the first principal component of P.C. (2) is considerably less than that of P.C. (1). The rankings from this index are also presented in Table 2. The John Muir Wilderness is ranked number one, Madulce, number two, etc. To see if the rankings of this index differed significantly from that of size, a Spearman's rank correlation test was again computed. The value of r_s was 0.57, which was significant at the 0.01 level; thus, the other characteristics were not able to overcome the dominant influence of size on the ordinal rankings.

A further attempt to validate the P.C. attractiveness indexes was made by comparing them with the U.S. Forest Service's Roadless Area Review and Evaluation Index (RARE). In 1971-72, the U.S. Forest Service made an inventory of roadless undeveloped Forest Services areas which generally conformed to the definition of a wilderness stated in the 1964 Wilderness Act [P.L. 88-577]. The U.S. Forest Service then devised a procedure for assistance in selecting from the inventory those areas which appeared to have a high potential for possible inclusion into the National Wilderness Preservation System. These high potential areas were designated Wilderness Study Areas. Quality index ratings were compiled by the RARE process to compare inventoried roadless areas and existing wilderness areas.

The RARE process involves evaluating existing wilderness and wilderness study areas according to (a) scenic quality; (b) isolation, size, and camping quality; (c) variety and (d) other characteristics. Forest personnel subjectively assign a weight to each of these categories by attaching weights to specific criteria under various categories. An aggregate index is then obtained by employing the subjectively assigned weights to the major criteria and summing. The ordinal rankings associated with the RARE index for the same set of wilderness areas under consideration are also given in Table 2. Based on Spearman's rank correlation test, the RARE index's rankings were significantly different from those obtained by size at the 0.05 level, but not at the 0.01 level of significance.[5] The computed t value of 2.65 is to be compared with the critical t values (37 degrees of freedom) of 2.03 and 2.72 respectively. The RARE index rankings differed significantly from those obtained by P.C. (1); however, they did not differ from those associated with P.C. (2). In addition, the rankings based on P.C. (1) and P.C. (2) did not differ from each other at the 0.01 level based again on the Spearman's test.

These results indicate that size is an influential component in the attractiveness of a wilderness area. This result holds for both the best subjective attractiveness index available for the California index areas (the RARE index) and those constructed by means of the analytical principal components method. If one assumes that the primary purpose of recreating at wilderness areas is to get away from more congested areas, then these results seem reasonable [Catton and Hendee]. The larger the areas, the more attractive it becomes.

In order to examine the consequences of alternative recreational opportunities on the demand for an area's services, the attractive-

[4]In addition, a slight change was made in the characteristics (i.e., precipitation replaced perimeter and size was incorporated). Several alternative characteristics were considered, but only these two sets are reported in the actual construction of the indexes.

[5]The formula which accounts for tied observations was used when appropriate [Siegel, pp. 206-210].

TABLE 1. Wilderness Characteristics[a]

		Scenic Quality					Access			Facilities	
Area	Size	Miles of streams	Number of mountain peaks	Number of lakes	Precipitation annual	Forest	Miles of trails	Number of entry and exit points	Length of perimeter	Number of campgrounds[b]	Campground family units[b]
	(acres)	(tenth of a mile)			(inches per year)	(acres)	(tenth of a mile)		(mile)		
Wilderness											
Agua Tibia	16,971	67.6	4	2	25	0	39.6	1	36	4	136
Caribou	19,080	1.0	6	63	35	19,080	18.7	3	37	4	134
Cucamonga	9,022	25.4	6	0	32	5,864	8.0	7	22	5	109
Desolation	63,469	61.5	20	148	36	63,469	73.0	19	49	9	588
Dome Land	62,561	100.5	4	0	13	51,300	31.7	10	79	1	40
Emigrant Basin	106,910	186.4	20	336	38	106,910	67.8	11	64	2	70
Hoover	47,937	236.0	31	130	23	47,937	44.4	15	72	15	332
John Muir	504,263	1,242.0	138	997	25	504,263	384.0	56	360	45	1,278
Marble Mountain	214,543	378.0	16	106	42	205,961	225.0	30	104	8	107
Minarets	109,559	299.0	27	190	33	109,559	130.0	17	94	22	731
Mokelumne	50,400	77.6	3	30	50	41,328	22.8	15	49	10	291
San Gabriel	36,137	102.4	6	1	35	2,168	18.8	10	35	12	420
San Gorgonio	34,718	43.0	11	2	38	32,288	39.2	8	42	4	145
San Jacinto	21,955	30.1	5	0	20	21,955	14.4	9	40	5	136
San Rafael	142,918	315.0	7	0	20	11,433	121.5	13	80	8	109
South Warner	69,547	173.2	7	10	17	36,860	68.4	11	60	4	84
Thousand Lakes	16,335	5.4	8	23	32	5,717	20.2	4	21	6	235
Ventana	97,602	297.0	14	0	38	25,376	100.5	13	81	9	287
Yolla Bolly	111,091	208.0	18	3	43	104,425	111.2	20	64	2	30
Primitive											
High Sierra	10,247	22.2	5	2	43	10,247	12.2	1	31	4	369
Salmon-Trinity Alps	285,756	505.2	37	84	36	217,174	450.0	53	158	13	345

TABLE 1. continued

Area	Size	Scenic Quality: Miles of streams	Scenic Quality: Number of mountain peaks	Scenic Quality: Number of lakes	Scenic Quality: Precipitation annual	Forest	Access: Miles of trails	Access: Number of entry and exit points	Access: Length of perimeter	Facilities: Number of campgrounbs[b]	Facilities: Campground family units[b]
	(acres)	(tenth of a mile)			(inches per year)	(acres)	(tenth of a mile)		(mile)		
Wilderness Study											
Cucamonga	3,500	8.8	6	0	32	3,500	8.2	4	13	4	68
Sheep Moutain	31,680	70.8	12	0	35	4,435	13.4	11	56	17	565
Hoover Extension	68,700	128.0	42	86	23	46,029	68.0	16	89	11	323
Mokelumne	9,818	17.0	0	7	50	9,818	18.4	3	24	8	270
Upper Kern	130,625	237.9	15	18	15	130,625	139.0	10	66	5	56
San Joaquin	5,500	22.8	1	1	33	5,500	8.0	3	16	6	199
White Mountain	112,000	336.6	14	0	17	49,280	1.2	16	114	0	0
Paiute	62,260	118.8	4	0	5	55,411	18.8	13	60	0	0
Portuguese	28,216	109.8	4	0	42	28,216	43.0	7	65	4	70
Etna	6,170	22.8	1	1	42	6,170	4.8	3	21	1	10
Shackleford	4,440	10.2	0	1	42	4,440	4.0	3	18	2	52
Johnson	4,400	13.0	0	0	42	4,400	5.6	3	17	1	6
Snoozer	20,000	35.6	2	0	42	20,000	23.8	6	44	4	38
Madulce	32,000	88.8	2	0	20	11,520	19.8	9	45	0	0
Mount Shasta	45,020	141.0	53	2	44	38,267	4.8	14	53	2	13
North Fork San Joaquin	33,580	82.8	7	3	33	33,580	52.8	10	43	12	247
Carson-Iceberg	80,205	225.6	31	68	45	71,382	77.0	21	98	13	2,254
North Fork American	45,000	129.0	9	69	55	35,550	58.4	24	84	16	293

[a] For a detailed account of how the entries in the table were obtained, see Wetzstein and Green.
[b] Improved campgrounds within five miles of a wilderness area.

TABLE 2. Rankings of Wilderness Areas Based on Various Attractive Indexes

		Principal component index 1		Principal component index 2		RARE	
Area	Size	Value	Rank	Value	Rank	Value	Rank[a]
1 John Muir	504,263	13.71	1	12.44	1	185	1
2 Salmon-Trinity Alps	285,756	6.74	2	11.02	11	171	5
3 Marble Mountain	214,543	3.48	5	11.10	9	174	4
4 San Rafael	142,918	1.96	15	12.18	4	147	13
5 Upper Kern	130,625	2.50	11	11.54	7	159	8
6 White Mountain	112,000	1.87	16	12.30	3	138	18.5
7 Yolla Bolly	111,091	2.54	10	10.42	15	114	28
8 Minarets	109,559	3.70	4	10.20	20	168	6
9 Emigrant Basin	106,910	2.86	6	11.10	10	182	2
10 Ventana	97,602	2.13	13	10.87	12	147	13
11 Carson-Iceberg	80,205	3.97	3	8.62	34	102	35
12 South Warner	69,547	1.54	17	11.35	8	138	18.5
13 Hoover Extension	68,700	2.57	8	10.20	19	163	7
14 Desolation	63,469	2.57	9	9.70	25	177	3
15 Dome Land	62,561	1.20	22	11.79	6	108	29.5
16 Paiute	62,260	1.28	21	12.01	5	125	23
17 Mokelumne	50,400	1.43	18	10.32	16	135	20
18 Hoover	47,937	2.58	7	9.30	30	157	10
19 Mount Shasta	46,020	2.06	14	10.63	13	150	11
20 North Fork American	45,000	2.13	12	8.67	33	158	9
21 San Gabriel	36,137	1.17	23	10.56	14	107	31.5
22 San Gorgonio	34,718	1.14	24	9.88	22	92	36
23 North Fork San Joaquin	33,580	1.34	19	9.33	29	120	26
24 Madulce	32,000	0.85	27	12.37	2	147	13
25 Sheep Mountain	31,600	1.32	20	10.01	21	139	16
26 Portuguese	28,216	1.07	25	9.34	28	124	24
26 San Jacinto	21,955	0.55	26	10.26	17	80	38
28 Snoozer	20,000	0.73	30	9.81	23	108	29.5
29 Caribou	19,080	0.80	28	10.24	18	121	25
30 Agua Tibia	16,971	0.68	33	9.77	24	84	37
31 Thousand Lakes	16,335	0.79	29	9.68	26	107	31.5
32 High Sierra	10,247	0.69	32	8.10	36	103	34
33 Mokelumne WSA	9,818	0.64	34	8.04	37	128	22
34 Cucamonga	9,022	0.72	31	8.13	35	74	39
35 Etna	6,170	0.43	37	9.37	27	139	16
36 San Joaquin	5,500	0.55	36	7.35	38	139	16
37 Shackleford	4,440	0.40	38	8.82	39	129	21
38 Johnson	4,400	0.39	39	8.89	32	104	33
39 Cucamonga WSA	3,500	0.55	35	4.29	31	115	27

[a] If two areas are ranked the same, e.g., eighteenth, then both are assigned the value 18.5. If three areas are ranked the same, e.g., twelfth, then all three areas are assigned a value of 13 as opposed to 12-14.

ness indexes developed above were incorporated into a proxy to account for the competitive effect of alternative wilderness areas.

Demand Function

An extension of the Hotelling-Clawson approach was chosen to represent the demand function for a specific area's services. Specifications similar to the one developed below have been formulated by others [e.g., Boyet and Tolley, Grubb and Goodwin, Johnston and Pankey, and Sinden]. An attempt was made to select a typical demand function to demonstrate the use of principal component attractiveness indexes to account for the competitive factor of alternative wilderness sites. With respect to the specification there also rises the question whether it would be better to refer to the equation as a use rather than a demand function. Grubb and Goodwin employ their function as a first step — a travel cost-visitation relationship — in deriving a demand curve for a particular recreational area. However, Sinden, and Boyet and Tolley refer to similar specifications as demand functions. It addition, it closely resembles a demand function since quantity demanded is assumed to be a function of its own price, income, and a variable accounting for substitution effects. Thus, the specification in equation (1) will be referred to as a demand function although some might prefer the term, use-relationship.

The postulated multiplicative demand model is:[6]

$$(1) \qquad v_{ij} = Ax_{1ij}^{\beta_1} x_{2i}^{\beta_2} x_{3i}^{\beta_3} x_{4ij}^{\beta_4} e_{ij}^{u}, \quad i = 1, \ldots, I \quad j = 1, \ldots, J$$

where v_{ij} is the number of visitor days from origin "i" to area "j" (one visitor day equals 12 visitor hours),

X_{1ij} is the distance between origin "i" and area "j", measured in total highway miles between zones, and is a surrogate for price,[7]

x_{2i} is the population of origin "i" in thousands,

x_{3i} is the median income of origin "i" measured in dollars, and

x_{4ij} is a proxy to account for the alternative recreational opportunities of a similar nature available to residents of different population origin zones.[8]

Interpretations of the variables are straight forward except for the alternative opportunities variable. "To adequately incorporate the effects of other recreation areas into an analysis, account would probably need to be taken of not only the number of alternatives but also their location and possibly some measure of size or quality" [Knetsch 1963, pp. 390-391]. The constructed variable attempted to incorporate these different factors. It is given by

$$(2) \qquad \sum_{\substack{j=1 \\ j \neq k}}^{J} (A_{.j}/D_{ij})/(A_{.k}/D_{ik}).$$

The variable measures the alternative opportunities to the k-th area from origin "i". The numerator expresses the hypothesis that the more attractive is an alternative wilderness area, as measured by the principal components index, $A_{.j}$, the more competition it poses for the k-th area. This competitive factor is, however, relative to the area's distance from origin "i". The farther it is away from origin "i", the less of a competing factor it becomes regardless of its attractive features. Thus, $A_{.j}$ is divided by distance with the result then summed over all of the alternative areas. A subset of alternative areas could have been chosen if it was felt that some of the areas were not viable alternatives for the given (k-th) area. The attractiveness and distance of alternative sites are relative to the given area; hence the numerator of equation 2 is divided by $A_{.k}/D_{ik}$ to account for this property.

Similar proxies have been employed previously. For example, Grubb and Goodwin employed

$$(3) \qquad C_{ij} = \sum_{j=1}^{n} \frac{\ln A_j}{D_{ij}}$$

[6]Various problems associated with the use of multiplicative models have been cited by a number of researchers [e.g., Teekens and Koerts].

[7]Some authors express this variable in terms of travel costs whiles others leave it in terms of highway miles [e.g., Burt and Brewer, and Sinden]. If travel costs between an origin and a site are assumed proportional to the highway miles between the areas, then the problem reduces to one involving units of measurement. Consequently, no difficulty exists, although one should bear in mind the units of measurements.

[8]The inclusion of measures of alternative recreational opportunities in a recreation area's demand function has been justified on heuristic grounds. Recently, however, there have been a couple of theoretical attempts to account for the substitution effects in outdoor recreational demand equations [see Burt and Brewer, and Cicchetti *et al.*]. In addition, the question rises whether it is better to use a (possibly poor) proxy for the unobservable variable, alternative opportunities, or to omit it and use the resulting misspecified equation. Wickens has shown that the bias of the estimates of coefficients of observable variables obtained by omitting the unobservable variable is always greater than the bias resulting from using even a poor proxy.

to account for the alternative areas' substitution effect for water recreational activities where A_j is the area of the jth lake and D_{ij} is distance. Johnston and Pankey also employed a similar proxy to capture the alternative opportunities effects. Other *ad hoc* "substitution" variables have been developed [Knetsch 1974, and Beamon]. However, none of these proxies employ the principal components method in an attempt to account for the many characteristics that make an area attractive.

A logarithmic transformation of the demand model in equation (1) was estimated using "permit" data collected by the forest service for 21 wilderness areas in California (see Table 1). All of the 58 origins (counties) and 21 existing wilderness areas were combined from cross-section data for the year 1975.[9] Ordinary least-squares was the estimation technique.[10]

The results in Table 3 show the overall goodness of fit ranging from $\bar{R}^2 = 0.36$ with the alternative opportunities variable omitted (eq. (1)) to $\bar{R}^2 = 0.57$ with P.C. (1) used in the alternative opportunities variable (eq. (2)). The Durbin-Watson values indicate no positive autocorrelation for eq. (2) at the 0.01 level of significance, inconclusive results for eq. (4), and positive autocorrelation for equations (1) and (3). However, the interpretation of the Durbin-Watson statistic using cross-section data is somewhat nebulous since the observations can be ordered in different ways.

The signs of the coefficients in every case are consistent with *a priori* expectations. The price and alternative opportunities coefficients are negative while the population and income coefficients are positive. Furthermore, the t-values indicate that almost all coefficients are highly significant. In every case, the alternative opportunity coefficient is significant and when compared with equation (1) indicates a substantial increase in the adjusted R^2 value. The exception occurs in equation (3) where the adjusted R^2 value only increases by 0.03. Thus, a relatively large improvement occurs when the substitution effect is taken into account by the constructed proxies.

In equation (4), the size of an area was used in place of the principal component indexes to develop the "competitive" factor. The overall goodness of fit, magnitudes of coefficients, and statistical tests for equation (4) are

[9] For a detailed listing of the data sources see Wetzstein and Green.

[10] Pooling data from the 58 origins and 21 wilderness areas assumes the coefficients are constant over all the wilderness areas. Application of the ordinary least-squares method is conditioned by this assumption and the assumption that the disturbance terms associated with the various wildernesses possess a scalar covariance matrix. Recently, Burt and Brewer, and Cicchetti *et al.* relax these restrictive assumptions and employ a simultaneous systems-equations approach to estimate the crossprice elasticities of various recreational areas.

TABLE 3. Estimated Recreation Demand Functions

						Alternative Opportunities[a]				
Equation	Dependent variable V	Constant	Price X_1	Population X_2	Income X_3	P.C. (1) $X_4^{(1)}$	P.C. (2) $X_4^{(2)}$	Size $X_4^{(3)}$	$\bar{R}^2$ [b]	D.W.
(1)		6.06	−1.74	0.83	0.11				0.36	1.28
		(6.83)[c]	(14.99)	(17.16)	(0.80)					
(2)		4.43	−0.70	0.87	0.31	−1.09			0.57	1.71
		(6.00)	(6.28)	(21.60)	(2.84)	(18.43)				
(3)		3.97	−0.79	0.83	0.14		−0.96		0.39	1.30
		(4.20)	(3.83)	(17.37)	(1.06)		(5.60)			
(4)		4.69	−0.88	0.85	0.23			−0.92	0.52	1.58
		(6.06)	(7.71)	(20.31)	(2.03)			(15.55)		

[a] P.C. (1), P.C. (2), and size indicate the attractiveness indexes employed in the construction of the alternative opportunities variable.
[b] $\bar{R}^2$ is the adjusted R^2 value.
[c] The values in parentheses represent t-ratios.

comparable to those obtained when P.C. indexes were employed. This conclusion is consistent with the results obtained in previous sections with respect to the ordinal rankings. Thus, size of an area appears to capture most of the wilderness area attractiveness for wilderness area users as it relates to competing sites.

Policy Implications

Important policy implications related to the introduction of new wilderness study areas into the system can be derived from the estimated demand functions. If new wilderness areas are introduced into the system, then the value of the alternative opportunities variable would change. Thus, the estimated substitution effects can be obtained from equations (2), (3), and (4) of Table 3. The percentage change in the number of visitor days from origin "i" to site "j" is given by

$$(4) \qquad \frac{v_{ij1} - v_{ij2}}{v_{ij1}} \cdot 100$$

where v_{ij1} is the predicted number of visitor days from "i" to "j" before the introduction of the new sites and v_{ij2} is the predicted number of visitor days from "i" to "j" after the introduction of all the new wilderness study areas. This percentage change can also be obtained from the estimated logarithmic form of the demand functions. Take the difference of the antilog of $\hat{\beta}_4 \ln X_{4ij}$ before and after the introduction of new study areas. Then divide this difference by the antilog of $\hat{\beta}_4 \ln X_{4ij}$ before the introduction of new sites. Multiplying this value by 100 will give the desired results.

Some illustrative results are presented in Table 4. For example, if all the new wilderness study areas, as given in Table 1, are introduced into the system, it will result in a 58.96 percent reduction in the number of visitor days from Los Angeles county to the Desolation wilderness area using the alternative opportunities variable constructed by P.C. (1). If size were used to construct the alternative opportunities variable, the reduction would be approximately 38 percent. Other substitution effects can be found from observing the entries of Table 4. In all cases, the substitution that would occur between existing and new wilderness areas is substantial. These results represent the maximum effects since it is assumed that little, if any, use currently exists at the study areas. Therefore, the actual substitution effects are prob-

TABLE 4. Some Estimated Substitution Effects after the Introduction of New Wilderness Study Areas

Alternative opportunities variables and origins	Wilderness areas		
	Desolation	San Rafael	Yolla Bolly
	Percent reduction in visitor days from origin "i" to destination "j"		
Principal component #1			
Los Angeles	58.96	61.47	58.66
San Francisco	57.62	55.21	57.31
Sacramento	68.81	62.43	65.17
Principal component #2			
Los Angeles	65.29	69.06	72.78
San Francisco	75.56	74.08	75.50
Sacramento	84.65	78.67	81.12
Size			
Los Angeles	38.10	43.03	38.40
San Francisco	34.08	34.53	35.14
Sacramento	38.33	37.10	38.27

ably somewhat lower than the estimated effects depending upon the present level of use at the new wilderness areas. Data are not available, however, to measure the current level of use at these sites.

Conclusions

Reliance on principal component attractiveness indexes to assess scenic beauty of public forests and wildlands not only provides direct guidance to public land management but it also furnishes indirect estimates of the demand for alternative recreational opportunities. The results indicate that estimates of recreation demand functions based on principal components attractiveness measures can provide substantially better explanatory capacity. However, indiscriminate use of principal components measures can obscure critical variables which might be of interest to management agencies. If particular policy instruments are related to certain variables, then the principal components approach can still be used in conjunction with explicitly introduced instruments. Also the method discussed in the paper can be used to develop alternative attractiveness indexes by combining physical characteristics of a wilderness with the subjective landscape measures of forest personnel or recreation users.

Substitution effects that would occur if new wilderness areas were introduced into the system are substantial. Even after allowing for the upward bias that may exist in these estimates due to the unmeasurable current use at the new study areas, these results supply public land managers with valuable inputs in their decision-making process.

With respect to the various indicators of attractiveness discussed in this paper, it appears that size of a wilderness area may work reasonably well as a proxy for attractiveness. This does not necessarily detract from the above results, but illustrates once again that simplistic approaches are sometimes difficult to improve upon.

References

Arthur, L. and R. Boster, "Measuring Scenic Beauty: A Selected Annotated Bibliography," USDA Forest Service, Gen. Tech. Report RM-25, May 1976.

Beamon, J., "Corrections Regarding the Impedance of Distance Functions for Several g(d) Functions," *Journal of Leisure Research,* 1976, pp. 49-52.

Boyet, W. and G. S. Tolley, "Recreation Projection Based on Demand Analysis," *Journal of Farm Economics,* 48 (1966): 984-1001.

Burt, O. R. and Brewer, D., "Estimation of Net Social Benefits from Outdoor Recreation," *Econometrica,* 39 (1971): 813-828.

Catton, William R. and John C. Hendee, "Wilderness Users . . . What do They Think?", *American Forests,* 74 (1968): 29-31 and 60-61.

Cicchetti, C. J., A. C. Fisher, and V. K. Smith, "An Econometric Evaluation of a Generalized Consumer Surplus Measure: The Mineral King Controversy," *Econometrica,* 44 (1976): 1259-1276.

Dhrymes, P. J. *Econometrics: Statistical Foundations and Applications* San Francisco: Harper and Row, 1970.

Grubb, H. W. and J. T. Goodwin, *Economic Evaluation of Water Oriented Recreation in the Preliminary Texas Water Plan,* Texas Water Development Board, September 1968.

Johnston, J. *Econometric Methods,* 2nd ed., New York: McGraw-Hill Book Company, 1972.

Johnston, W. E. and V. S. Pankey, "Some Considerations Affecting Empirical Studies of Recreational Use," *American Journal of Agricultural Economics,* 50, (1968): 1739-1744.

Knetsch, J. L., "Outdoor Recreation Demands and Benefits," *Land Economics,* 39 (1963): 387-396.

Knetsch, J. L., *Outdoor Recreation and Water Resources Planning,* American Geophysical Union, Water Resources Monograph Series 3, 1974.

Pub. L. 88-577, *Wilderness Act,* 78 Stat. 890, Sept. 3, 1964.

Pub. L. 91-190, *National Environmental Policy Act of 1969,* 83 Stat. 852, Jan. 1, 1970.

Siegel, S. *Nonparametric Statistics for the Behavioral Sciences.* New York: McGraw-Hill, 1956.

Sinden, J. A., "A Utility Approach to the Valuation of Recreational and Aesthetic Experiences," *American Journal of Agricultural Economics*, 56 (1974): 61-72.

Teekens, R. and J. Koerts, "Some Statistical Implications of the Log Transformation of Multiplicative Models," *Econometrica*, 40, (1972): 793-819.

Wetzstein, M. E. and R. D. Green, *The Effects of Introducing New Areas on Wilderness Use in California: An Economic Analysis*, unpublished U.S. Forest Service Report, Pacific Southwest Forest and Range Experiment Station, Berkeley, California, 1977.

Wickens, M., "A Note on the Use of Proxy Variables," *Econometrica*, 40 (1972): 759-761.