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"Estimating Congestion Costs and Optimal Admission Fees: An Indexation Approach"

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Estimating Congestion Costs and Optimal Admission Fees: An Indexation Approach

ABSTRACT

Rationing the use of fixed capacity facilities subject to congestion costs by using fees is complicated in practice by the difficulty of estimating quality-adjusted demand schedules for the facility. Previous approaches to measuring congestion costs have met with limited success. An alternative methodology based on indexation techniques is presented and then applied to a popular urban lake in Arizona. It is concluded that estimating quality-adjusted user fees through the use of indexation techniques has several advantages over earlier approaches.

Introduction

Traditionally, economists have advocated the use of fees to ration the use of fixed capacity facilities subject to congestion costs (e.g. developed recreation sites, museums, or urban parks). However, the selection of the fee that maximizes net benefits at a particular level of use requires a measurement of congestion costs, and earlier multiple regression approaches with a proxy variable for congestion (e.g., users per acre) have met with only limited success (Cicchetti and Smith, Deyak and Smith, McConnell). The purpose of this research is to: (1) propose an alternative methodology for deriving quality-adjusted demand functions from readily available willingness to pay (WTP) schedules at unrestricted levels of use (the indexation methodology) and (2) provide an empirical illustration of how the indexation approach may be employed to estimate congestion costs and optimal admission fees.

User Fees and Quality-Adjusted Demand Curves

Rationing a fixed capacity resource by imposing a user fee is complicated in application by the difficulty of estimating a quality-adjusted demand curve. As the level of facility use declines, congestion costs decline, causing the willingness-to-pay of facility users to rise. The benefit of enhancing the quality of the experience to users as participation levels and congestion costs decline must be reflected in the estimated demand curve or user fees will be systematically underestimated.

The estimation problem is illustrated in Figure 1. As the number of facility users increases, additional congestion costs are incurred. For a relatively homogeneous group of users, this can be illustrated by willingness

to pay schedules falling with level of facility use, $WTP_1 \cdots WTP_N$ (Fisher and Krutilla).[1] Notice that none of these individual willingness to pay schedules constitutes a demand function for the facility since only one point on each schedule will be observed. The quality-adjusted demand curve is generated by varying the participation price and computing the resulting number of facility users (Freeman and Haveman). For example, when an admission fee of F_1 is charged, Q_1 individuals will participate since only that number of users have a willingness to pay in excess of F_1 when the level of facility use is Q_1. Thus, point "a" lies on the quality-adjusted demand curve (D). Repeating this process, a series of points lying on this curve can be identified.

The unrestricted level of use occurs at Q_n where the uncongested willingness to pay of the marginal user equals the average congestion cost and no fee is charged. Typically, the resource manager has information about WTP_N, the willingness to pay of facility users at the unrestricted level of use. Imposing a fee based on this information in an attempt to lower facility use to a prespecified level will result in a supraoptimal number of users participating.[2] For example, if the level of use were to be limited to Q_2, WTP_N would indicate that a fee of F_3 would be sufficient when in fact a fee of F_2 is required. The difference between these two fees reflects the quality improvement associated with the reduction in average congestion costs experienced by the users when the level of use is reduced from Q_N to Q_2.

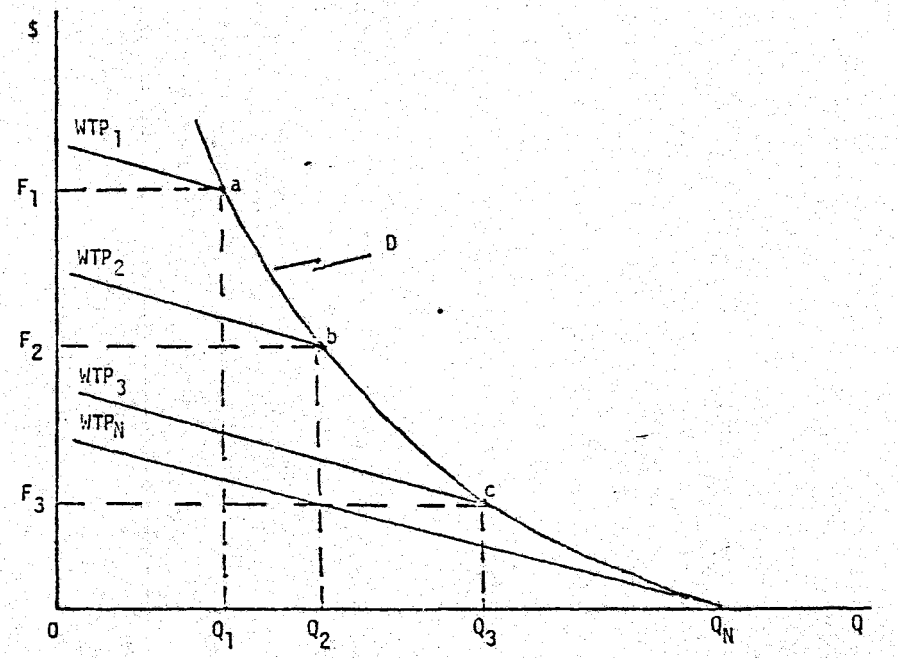
The implementation problem facing the use of fees to ration the use of a fixed capacity facility subject to congestion costs arises directly out of the difficulty of estimating how congestion costs will be reduced as participation rates decline. In particular, an estimate for the change in average congestion cost is needed so that a quality-adjusted demand curve

can be estimated from the readily available schedule of unrestricted willingness to pay.

Indexation Measures of Congestion Costs

Consider two groups of facility users, one subject to high congestion costs (say weekend users) and the other subject to comparatively low congestion costs (say weekday users). Other things equal, the average willingness to pay of the congested group would be expected to be less than the average willingness to pay of the group of less congested users. But other things are not constant. Any differential in willingness to pay between the two groups may arise as the result of distributional differences in several factors other than congestion costs. Differences in income levels, frequency of use, and distance from site are just a few examples of variations between the two groups that could partially explain willingness to pay differentials. Indexation is a technique that isolates the impact of these noncongestion factors on the ratio of the uncongested to congested average willingness to pay of the two groups. That is, this procedure breaks down the willingness to pay differential between the two groups into two categories: 1) a difference resulting from factors influencing willingness to pay other than congestion costs, and 2) a residual unaccounted for by differences in noncongestion factors which may result largely from congestion.[4]

The willingness to pay differential between the congested and uncongested groups of users is disaggregated by constructing the Laspeyres and Paasche indexes of willingness to pay differences. The Paasche index of willingness to pay differences is the hypothetical ratio of the mean willingness to pay of uncongested to congested facility users, assuming both groups were distributed among noncongestion factors influencing willingness to pay as



Number of Facility Users

Figure 1. Derivation of a Quality-Adjusted Demand Curve

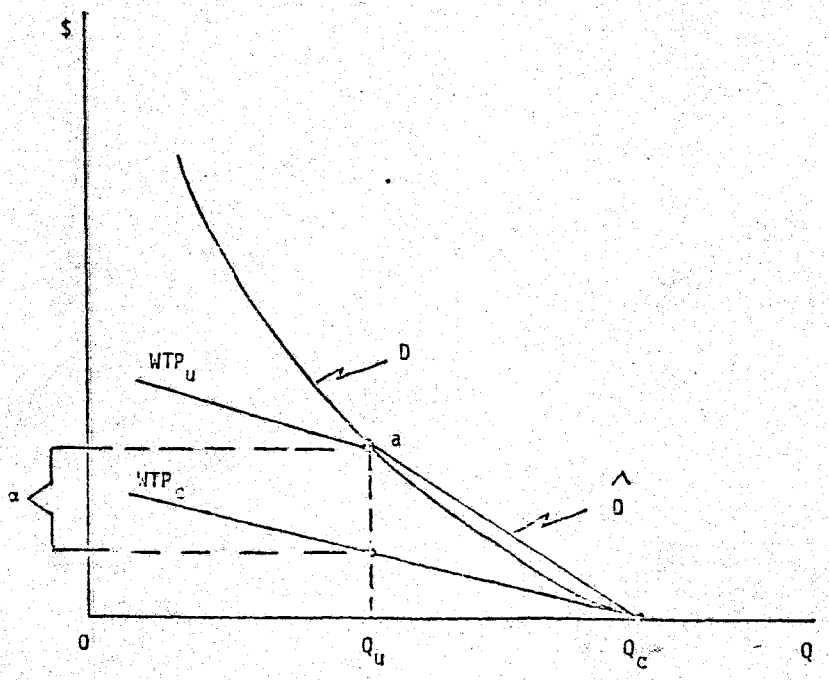


Figure 2. Linear Approximation of a Quality-Adjusted Demand Curve

the uncongested users actually were. In contrast, the Laspeyres index of willingness to pay differences is the hypothetical ratio under the assumption that both groups of users had the distribution of noncongestion factors associated with the congested group. The mathematical form of the index of willingness to pay differences is:

$$\frac{\sum W_u \cdot D_u}{\sum W_c \cdot D_u} \text{ (Paasche) and, } \frac{\sum W_u \cdot D_c}{\sum W_c \cdot D_c} \text{ (Laspeyres)}$$

where,

W_c = the average willingness to pay of individuals in the congested group of users who are within a willingness to pay determinant category (e.g., income, frequency of visits or distance from site), other than congestion costs.

W_u = the average willingness to pay of individuals in the uncongested group of users who are within a willingness to pay determinant category, other than congestion costs.

D_c = the percent of the congested group of users within a willingness to pay determinant category, other than congestion costs

D_u = the percent of the uncongested group of users within a willingness to pay determinant category, other than congestion costs.

The index of willingness to pay differences is essentially an estimate of the ratio of uncongested to congested willingness to pay after adjustment for differences in the noncongestion determinants of willingness to pay considered. Having accounted for other determinants of willingness to pay which affect the differential in average willingness to pay between the two groups, the residual difference becomes an estimate for the difference in average congestion cost at the two levels of facility use.

The estimate for the change in average congestion cost determined by indexation can then be used to estimate a quality-adjusted demand curve for the congested group of users. This is illustrated in Figure 2. The

estimated change in average congestion cost resulting from reducing the level of use from the congested level of use (Q_c) to the less congested level of use (Q_u) is α. That is, the willingness to pay of the congested group of users (WTP_c) is estimated to increase by α as the level of use falls from Q_c to Q_u. Adding α to WTP_c allows the identification of point "a" on the quality-adjusted demand curve (D). Connecting "a" and Q_c yields a linear approximation to D (i.e. $\hat{D}$).

An Empirical Application: Measuring Congestion Costs at an Urban Fishing Lake

Personal interviews were conducted at Chaparral Lake (Scottsdale, AZ) each week for a one year period (Martin, Garifo and Gum). Two weekdays and one day of the weekend were randomly selected each week to conduct interviews. A total of 471 adult users were interviewed over this period, constituting 12% of the total number of adult permits issued. The questionnaire consisted of 29 items including willingness to pay for a six month fishing permit, distance traveled to site, income and various demographic variables. In addition, the total level of use (i.e., the total number of permittees participating) was tabulated for each interview day.[5] For indexing purposes, the interview data acquired was partitioned so that unemployed or retired individuals; persons not fishing for trout; and individuals fishing at night, on holidays, or during inclement weather were omitted from the sample. For the remaining individuals in the sample, the participation levels were approximately 2.4 times higher during weekends than during weekdays. Furthermore, the mean willingness to pay for a six month permit of the former group was $8.07 while that of the latter group was $6.79. This amounts to an unadjusted ratio of mean willingness to pay for the two groups of 1.187, indicating that

Table 1. Willingness to Pay of Weekday Users as a Percentage of Weekend Users, Adjusted for Various Determinants of Willingness to Pay Differentials Between Weekday and Weekend Users of Chaparral Lake in 1977-78.

	Index of Willingness to Pay Differences		Marginal Effect of Factor	
	Laspeyres	Paasche	Laspeyres	Paasche
Unadjusted Willingness To Pay Ratio (Weekday/Weekend)	118.7	118.7	-	-
Explanatory Factors				
A. Income-Occupation	116.2	103.2	-2.5	-15.5
B. Number of Visits	119.4	122.0	3.2	18.8
C. Distance to Site	96.3	101.9	-23.1	-20.1
D. Size of Catch	116.5	104.6	20.2	2.7
E. Permittee Age	124.5	106.8	8.0	2.2
Fisher Ideal Price Index = 115.3				

Table 2 - Adjusting User Fees for Changes in Congestion Costs.

Administratively Selected Level of Use	Percentage Reduction In Use Levels ($\%\Delta Q$)	Percentage Increase in Average Willingness to Pay ($\%\Delta \bar{W}$)	Fee Adjustment($) ($\alpha$)
22	57.7	15.3	1.24
32	38.5	10.2	0.82
37	28.8	7.6	0.62
42	19.2	5.1	0.41
52	0	0	0

the less congested weekday users were willing to pay 18.7% more, on average for the fishing experience than the more congested weekend group of users.

Indexation Results

Having accounted for several factors influencing willingness to pay by selecting weekday and weekend anglers with similar fishing experiences, a willingness to pay differential of 18.7% still remained between the two groups. To isolate what portion of this differential is attributable to congestion cost differences, several additional factors influencing this differential were then accounted for through indexation.

In selecting variables to be used in indexing, three criteria were employed. First, only factors generally recognized as determinants of recreation demand, or as being closely correlated with willingness to pay, were selected. Second, the indexed factors are not directly related to congestion costs as such. Third, factors were either considered simultaneously, or chosen where the apparent relationship with other factors was one of independence. The following factors were selected using these three criteria: income, occupation, visits per season, distance from residence to lake, total catch on day interviewed and age.[7]

Income - Occupation Adjustment. Income levels ranged from $5,000 to $25,000 per year for weekday and weekend users interviewed. Weekend respondents had a higher average income ($12,837) than weekday respondents ($12,391). Occupations of interviewed users were exhaustively classified into 5 categories: professional and technical, managerial, clerical and sales, production, and service. For indexation, income and occupation differences between the two groups of users were treated simultaneously since the two factors are correlated. In particular, the income range of the users was

divided into four $5,000 increments. Combining this classification with the 5 categories for occupation resulted in a 20 cell income-occupation distribution for lake users.

Imposing the lower income distribution of the weekday users on the weekend group resulted in an adjusted Paasche index of mean willingness to pay of 103.2 (see Table 1). Imposing the higher income distribution of the weekend users on the weekday group resulted in an adjusted Laspeyres index of 116.2. This amounts to marginal effects of -15.5 and -2.5 for the Paasche and Laspeyres indexes respectively, compared to the unadjusted ratio of mean willingness to pay for the two groups of 118.7. That is, if the two groups of users had an identical distribution among income - occupation cells, the weekday users would still be willing to pay, on average, 3.2 to 16.2 percent more for the fishing experience.[8]

Adjustments for Visits per Season, Distance to Site, Size of Catch, and Age of Permittees. The weekend users on the average were younger, had less accessibility to the lake, exhibited a higher rate of participation (visits per season), and experienced greater success at fishing than the weekday participants. Imposing the age, accessibility, participation, and catch size distributions of the weekend users on the weekday group (Laspeyres) resulted in marginal changes of 8.0, -23.1, 3.2, and 20.2 respectively. These four factors constitute a total marginal change in the Laspeyres Index of 8.2, i.e., a weekday group with the same age, accessibility, participation, and success distributions as the weekend users would be willing to pay 8.2% more for the fishing permits. Alternatively, giving the weekend group the weekday users age, accessibility, participation, and success distributions (Paasche) resulted in marginal changes of 2.2, -20.1, 18.1, and 2.7 respectively, or a cummulative effect of 2.9%. That is, weekend users

would be willing to pay only 2.9% more for the permits if the distributions of their nonincome factors were similar to those experienced by weekday participants.

In summary, the two groups of users have been made comparable with respect to employment status, type of fish caught, high fishing success periods and daytime use by selecting interviews conducted under these conditions. The fishing experience is comparable with respect to these factors. In addition, six other factors which partially account for the mean willingness to pay differential between the two groups were evaluated through indexation. Giving the congested and uncongested groups the same distribution across income - occupation, number of visits per season, distance to site, size of catch, and permittee age categories, results in an adjusted mean willingness to pay of the uncongested group between 6.8 and 24.5% higher than that of the congested group. Computing the Fisher Ideal Price Index (i.e. the square root of the product of the Laspeyres and Paasche Indexes) yields a final adjusted estimate of 115.3. That is, a residual difference of 15.3% remains unexplained, a residual attributed to the change in average congestion cost between the two groups.

Adjusting User Fees For Changes in Congestion Costs at Chaparral Lake

The elasticity of weekend users' average willingness to pay with respect to level of facility use ($\varepsilon_{\bar{w}Q}$) is assumed to be constant over use levels under consideration. The results of the empirical study of congestion costs at Chaparral lake indicate that the average willingness to pay of weekend users ($\bar{w}$) increases by 15.3% when the level of facility use (Q) changes from the seasonal average for weekend use (52 anglers) to the seasonal average for weekday use (22 anglers). Reducing weekend use to the average weekday use would amount to a reduction of 57.7% in the level of weekend facility use. The estimated $\varepsilon_{\bar{w}Q}$, then, is:

$$\varepsilon_{\bar{w}Q} = \%\Delta\bar{w}/\%\Delta Q$$
$$= 15.3\%/57.7\%$$
$$= 0.265$$

The fee adjustment required to account for the quality improvement accompanying a less congested fishing experience (α) is simply the estimated change in average congestion cost ($\Delta\bar{w}$) associated with reduced use levels. That is,

$$\alpha = \alpha(Q)$$
$$= \bar{w}_0(\varepsilon_{\bar{w}Q})(\%\Delta Q)$$

where $\bar{w}_0$ is the average willingness to pay of weekend users at unrestricted levels of use. Substituting estimated values for Chaparral lake gives:

$$\alpha = \$8.07\ (0.265)(\%\Delta Q).$$

The $\%\Delta\bar{w}$ and α for various levels of weekend use below the unrestricted level of 52 permittees are presented in Table 2. If the weekend level of use were to be reduced to the average weekday level of use by imposing user fees, a 57.7% reduction in the number of anglers would result with an accompanying 15.3% increase in the weekend users' average willingness to pay. To reach this lower level of use, the user fee would have to be increased an additional $1.24 to reflect the change in average congestion cost experienced by the users. A less dramatic reduction would be to lower the weekend level of use to 42 anglers, a 19.2 % reduction in use level. The associated 5.1% increase in the weekend users' average willingness to pay resulting from this change would require a $0.41 increase in the user fee above that indicated by the unrestricted willingness to pay schedule.

Finally, the quality-adjusted demand curve is estimated by adding the fee adjustment schedule to the estimated unrestricted willingness to pay function for weekend users.

Conclusion

Measuring congestion costs using the Laspeyres and Paasche indexes of mean willingness to pay has several advantages over direct estimation techniques. The use of oversimplified proxy variables, like number of users per unit of facility area, is completely circumvented. Moreover, the additional expense of turning to more realistic proxy variables, like encounters, can also be avoided. Also, the specification of an *a priori* functional relationship between willingness to pay and level of facility use, required in multiple regression analyses, becomes unnecessary.

In using indexation techniques, care must be exercised in accounting for all relevant determinants of willingness to pay other than congestion costs. Omission of key factors can bias the residual estimate for the change in average congestion costs. Accordingly, information on a variety of factors influencing willingness to pay levels must be collected from interviewed users. Careful attention to interviewing users with similar recreation experiences can greatly reduce the number of factors that must be accounted for through indexation. It should also be noted that the indexation approach to measuring congestion costs requires a less congested comparison group. Thus, facilities constantly subject to high congestion costs cannot be evaluated with this technique. Finally, estimates for quality-adjusted demand schedules and user fees can be improved by comparing high congestion users to several groups of less congested users. By estimating changes in willingness to pay over several levels of use, the assumption of constant elasticity of mean willingness to pay with respect to level of facility use can be relaxed.

The phenomenal growth in demand for outdoor recreation in the United

States is well documented (Fisher and Krutilla). Assessing the impact of congestion on consumer welfare in recreation facilities can realistically be expected to become increasingly important. Laspeyres and Paasche indexes of willingness to pay are versatile evaluation tools for this purpose.

Endnotes

1. Throughout this analysis it is assumed that tastes for congestion avoidance are homogeneous. That is, $c_i(Q) = C(Q)/Q$, for all i, any Q where C(Q) is total congestion cost and $c_i(Q)$ is the congestion cost experienced by individual i when the total number of facility users is Q. For a discussion of the ramifications of heterogeneous tastes for congestion avoidance on optimal admission fees see Freeman and Haveman.

2. "Optimal" admission fees in this context are efficient in a second-best sense. Unless the administratively selected level of use is the level which maximizes net benefits of facility use, optimality in the first-best sense will not be attained. For a discussion of equity-efficiency tradeoffs relevant to selecting a target level of use see Cory.

3. R^2 values ranged from .043 to .064.

4. The use of indexation techniques is discussed in detail by Gwartney in his study of racial discrimination.

5. Willingness to pay questions were asked for the fishing experience as is, one for which creel limits were doubled, and a no stocking fishing environment. Both direct response and bidding game answer were solicited. The results of willingness to pay estimations, as well as estimates of net program benefits, are reported in Martin, Garifo and Gum.

6. The lake was stocked every two weeks with higher success fishing lasting for one week. The average fishing success of the anglers was 0.29 and 0.26 trout per hour for the high success weekday and weekend users respectively, with no significant difference between the means at the 5% confidence level. Daytime fishing was defined as fishing between 6:00 a.m. and 6:00 p.m. A total of 49 interviews were taken under the conditions discussed above.

7. The empirical findings of Martin, Garifo and Gum, as well as a large body of previous research on recreation demand, indicated the importance of these factors in determining willingness to pay. Income is the single factor that may have violated the second criterion. Freeman and Haveman discuss the theoretical implications of income and congestion costs being correlated. However, since no clear cut empirical evidence exists in this regard, the assumption of homogeneous tastes for congestion avoidance was adopted.

8. The downward adjustment of the unadjusted ratio after controlling for income-occupation differences is consistent with the empirical finding of Martin, Garifo and Gum that urban fishing at Chaparral lake is an inferior good.

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