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EQUITY-EFFICIENCY TRADEOFFS IN NATURAL RESOURCE MANAGEMENT: THE CASE OF CONGESTION

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ABSTRACT

Resources are allocated efficiently when the net benefits resulting from their use are maximized. Equity considerations in resource use focus on the distribution of net benefits among affected individuals and its desirability. In some applications, the relationship between equity and efficiency goals in multiple objective planning can be systematically evaluated by extending the conventional benefit-cost analysis of a resource policy. For illustrative purposes, this methodological extension is applied to the problem of rationing the use of a fixed-capacity facility. Equity and efficiency drawbacks of traditional rationing policies are examined, and an alternative policy is proposed, based on an explicit evaluation of equity-efficiency tradeoffs. Policy implications are discussed.

INTRODUCTION

Given relevant technological and institutional constraints, resources are allocated efficiently when the net benefits resulting from their use are maximized. A particular natural resource policy is preferred on efficiency grounds when the excess of total benefits over total costs exceeds that which would result from alternative policies. Equity considerations, on the other hand, are concerned not with the magnitude of total benefits and costs but with their distribution among affected parties. A particular natural resource policy is preferred on equity grounds when the incidence of net benefits among benefit-cost groups is more desirable than that resulting from alternative policies.

Within the context of multiple objective planning, it is routinely argued that

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the promotion of the twin goals of allocative efficiency and distributive equity in resource use constitutes an integral part of sound natural resource management. Yet the interrelatedness of equity and efficiency goals is poorly understood, and their interaction is infrequently evaluated in a systematic fashion. In particular, it is difficult for decision makers to assess the relative merits of alternative policies when some are preferred on efficiency grounds while others have significant equity advantages.

In some applications, the traditional efficiency analysis of a proposed resource policy can be extended to explicitly determine the relationship between equity and efficiency considerations. This extension, however, requires an alteration in the value judgments which underlie benefit-cost analysis as commonly practiced. It is argued in this paper that by explicitly accounting for distributional impacts, this type of extension of an efficiency analysis provides valuable information for decision making, since in general effective resource management will require determining an optimal mix of equity and efficiency outcomes.

These propositions can be illustrated by considering a common resource management problem; namely, rationing the use of a fixed-capacity facility (e.g., developed recreation sites, museums, or urban parks). The following section of this paper discusses the welfare implications of facility overuse, while section three analyzes the efficiency and equity limitations of traditional rationing policies. By extending the conventional efficiency analysis, section four proposes an alternative solution based on an evaluation of equity-efficiency tradeoffs. Finally, policy implications are discussed, with emphasis on the utilization of the additional information provided by this approach.

EFFICIENCY IMPLICATIONS OF CONGESTION EXTERNALITIES

The welfare implications of the existence of congestion externalities associated with the level of facility use are illustrated in Figure 1. As the number of users (Q) increases, total benefits rise at a decreasing rate. The gain to the marginal user (MG_Q) consists of his uncongested willingness to pay minus the average congestion cost experienced when the number of facility users is Q.[1] The existence of congestion externalities implies that the use of the facility by

[1] Throughout this analysis it is assumed that tastes for congestion avoidance are homogeneous. That is,

$$c_i(Q) = C(Q)/Q, \text{ for all i, any Q}$$

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 [1].

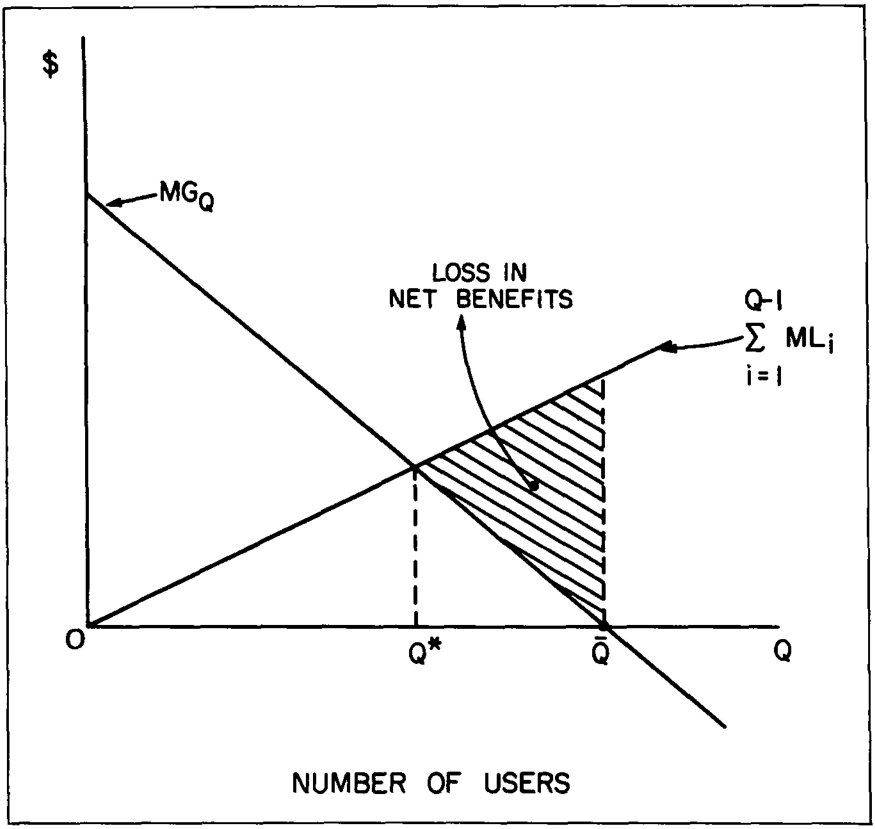

Figure 1. Net benefits and facility overuse.

the marginal user imposes additional congestion costs on the Q-1 inframarginal users (e.g., increased noise, additional waiting time, decreased amenity value, etc.). The marginal loss imposed on the Q-1 inframarginal users by the presence of the marginal or Q^{th} user $\left(\text{i.e., } \sum_{i=1}^{Q-1} ML_i\right)$ reflects the inframarginal users' decreased valuation of the services provided by the facility, and is an increasing function of the level of use.

An efficient level of use occurs when $Q=Q^*$ since

$$MG_Q(Q^*) = \sum_{i=1}^{Q-1} ML_i(Q^*). \tag{1}$$

That is, net benefits from use of the facility are maximized when the gain to the marginal user equals the marginal loss his presence imposes on the Q-1 inframarginal users. The unrestricted level of use $\bar{Q}$, however, will exceed Q^* since an individual user will participate as long as his marginal gain is positive. This supraoptimal level of use results in a loss of net benefits (namely, the shaded triangular area in Figure 1). Each additional user beyond Q* imposes marginal losses on inframarginal users in excess of the gain he enjoys by participating. Thus, to operate this facility efficiently, a rationing policy must be adopted that will restrict use to Q*.

TRADITIONAL RATIONING POLICIES

A rationing policy frequently advocated on efficiency grounds is the imposition of user fees. As illustrated in Figure 2, a user fee of t* would be required to ration facility use to Q*. The payment of the fee has the effect of lowering the original marginal gain schedule (MG_Q) by the amount of the charge (MG_Q'). Individuals beyond Q* will no longer participate since their marginal

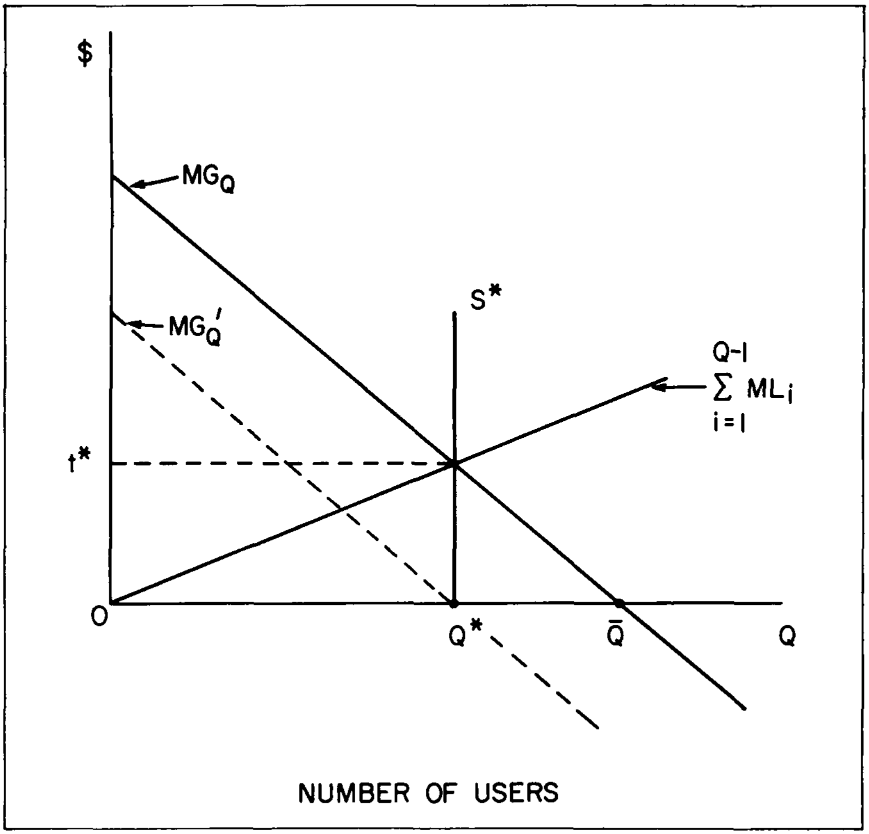

Figure 2. Traditional rationing policies.

gain after payment of the fee is negative. An efficient level of use is secured (i.e., net benefits from facility use are maximized) since only those who value facility services the highest, namely individuals 1 through Q*, will gain access.[2]

Critics of using charges to allocate the use of a facility subject to congestion externalities argue that fees only succeed in reducing the level of use at the expense of lower income users. That is, many of those who choose not to participate after the imposition of the fee will be among low income groups, which is clearly inequitable. This would, in fact, be the case if uncongested willingness to pay is positively related to income. Under this plausible assumption, MG_Q would be directly correlated with income so that user income would decline as Q increases. Consequently, individuals from Q* to $\bar{Q}$, whose marginal gain becomes negative after payment of a fee t*, would be characterized by nonparticipation and lower relative income levels.

In a desire to equitably allocate the use of a fixed-capacity facility, resource managers frequently opt for a reservation or first-come-first-serve rationing policy. This amounts to setting a standard (S*) for facility use whereby only Q* users will be allowed entrance. Such a rationing policy has equity advantages in that all potential users of the facility have equal opportunity to participate regardless of income characteristics. Unfortunately, reservation systems are inefficient. By arbitrarily allowing entrance, there is no guarantee that those who value the facility the highest (in terms of willingness to pay) will actually be able to participate. Net benefits from facility use will not be maximized since individuals with $MG_Q < t^*$ can gain access as easily as those with $MG_Q > t^*$.

Traditional rationing policies leave decision makers in an unenviable quandary: either use of the facility can be rationed through a system of fees which may be inequitable, or through a reservation system which is inefficient. Faced with this either-or alternative, reservation systems are frequently adopted, arguing that the ensuing loss in net benefits is a price worth paying to ensure that all potential users have equal opportunity to participate. The following section proposes a compromise rationing policy based on an explicit accounting of equity-efficiency tradeoffs.

SOCIALLY EFFICIENT USER FEES

Determining an optimal level of use based on an efficiency analysis has the virtue of assuring decision makers that imposing a rationing policy is a potentially worthwhile undertaking. Since the sum of the marginal gains exceeds that of the marginal losses, it is possible for beneficiaries to fully compensate losers and still be better off. Such a situation is termed a potential Pareto

[2] Notice that the revenue generated by the fees (t*Q*) has no welfare implications since it simply constitutes a transfer from facility users to facility administration, and it is assumed neither group is dispreferred relative to the other.

improvement, as opposed to an actual Pareto improvement where compensation is actually paid.

By imposing a fee of t*, individuals from Q* to $\overline{Q}$ will no longer participate since their marginal gain after payment of the charge is negative. This allocative outcome constitutes a potential, not actual, Pareto improvement since these users of the facility will not receive compensation for their losses which result from the imposition of this user fee policy. As a result, a difficult question still remains as to how to value these losses relative to the gains of users 1 through Q*.[3]

Conventional benefit-cost analysis maintains that gains and losses should be weighted by market power. That is, the efficiency decision rule is based on an evaluation of the unweighted willingess to pay of facility users. Willingness to pay, of course, consists of sums of money, sums which will obviously vary according to an individual's ability to pay. Critics of user fees argue that the value judgment inherent in this unweighted accounting scheme is inappropriate. Specifically, it is maintained that equitable use of facility services requires that the gains and losses of lower income users be given more weight than gains and losses accruing to higher income individuals.[4]

An alternative specification of the decision rule used to determine an optimal level of use can be formulated which incorporates differential weighting of gains and losses to various income groups; namely,

$$MG_Q(Q) \cdot MU_Q(Y) = \sum_{i=1}^{Q-1} ML_i(Q) \cdot MU_i(Y) \tag{2}$$

where $MU_i(Y)$ is the marginal utility of income to the i^{th} user. Under this criterion, an optimal level of use occurs when the net benefit to the marginal user weighted by his marginal utility of income equals the weighted marginal cost his use imposes on others. The efficiency decision rule (1), then, is simply the special case of (2) where the marginal utility of income is assumed constant for all individuals.

The allocative significance of this extension of the standard analysis is illustrated in Figure 3. If it is assumed that the marginal utility of income is diminishing and that income is positively related to uncongested willingness to pay, then it follows that:

$$MU_Q(Y) > MU_{Q-1}(Y) > \ldots > MU_1(Y) \tag{3}$$

The unweighted efficiency decision rule (1) is satisfied at Q* with the required fee equaling t*. Dividing both sides of (2) by $MU_Q(Y)$ leaves $MG_Q(Q)$ schedule

[3] Individuals 1 through Q* will gain despite payment of the fee t* as long as they are not excluded from the benefits which accrue from the tax revenues.

[4] For a discussion of Pareto optimality and distributive justice [2].

unchanged but lowers the $\sum_{i=1}^{Q-1} ML_i(Q)$ schedule since each inframarginal user's loss (i.e., $ML_i(Q)$) is multiplied by $MU_i(Y)/MU_Q(Y)$ which is less than one. Consequently, (2) will be satisfied at a level of use $Q^{**} > Q^*$ and the required fee will fall to $t^{**} < t^*$.

Advocating the use of t^{**} to ration the use of the facility will involve a loss in unweighted net benefits. This efficiency cost is the result of allowing the level of use to rise to $Q^{**} > Q^*$, and is represented by the shaded triangular area in Figure 3. Contrasted to this, the imposition of the allocatively efficient user fee t^* implied by (1) will result in no efficiency cost since all costs and benefits are weighted equally, regardless of user characteristics. By explicitly accounting for the distributional impacts of imposing a user fee system, the efficiency cost which results from charging the socially efficient user fee t^{**} has a straightforward interpretation; that is, it is the price, in terms of foregone net benefits, deemed worth paying to insure that net benefits accrue to a preferred group, namely lower income users from Q^* to Q^{**}.

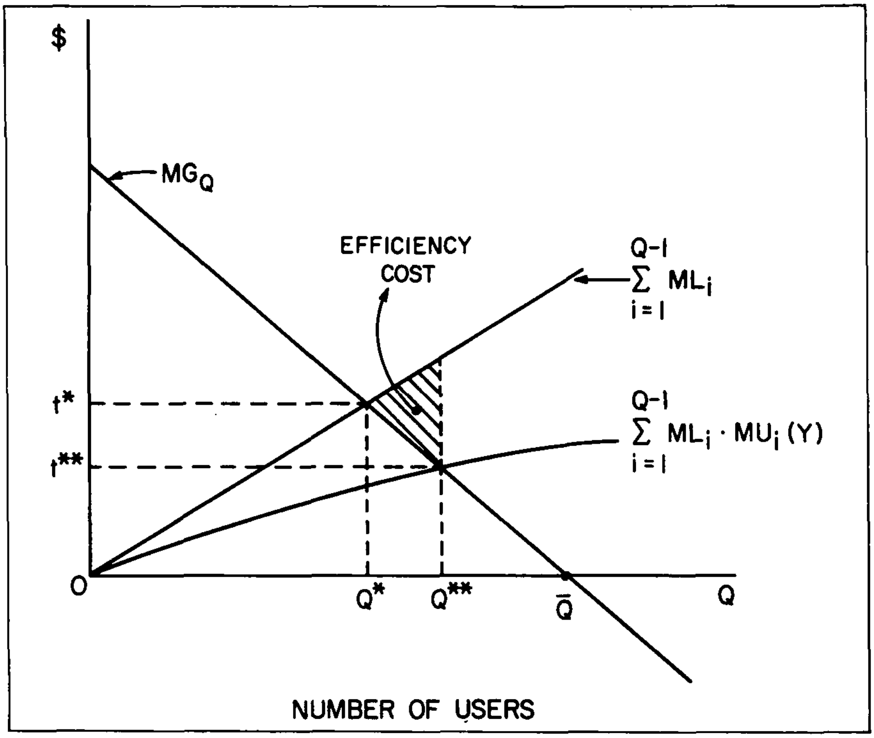

Figure 3. Socially efficient user fees.

Equity-Efficiency Tradeoffs and Decision Making

In general, the specification of a socially efficient toll will depend on the set of marginal utility weights adopted: the more egalitarian the selection, the larger the permissible level of use and the smaller the required fee. A convenient one-parameter representation for the set of marginal utility weights is given by the following constant elasticity marginal utility function:

$$MU(Y) = Y^{-\eta}, \; 0 \leqslant \eta < 1. \tag{4}$$

As the value of η increases, greater relative weight is given to the gains and losses of lower income individuals since this functional form implies that a one per cent increase in income is associated with an η per cent decrease in marginal utility.[5]

If marginal utility weights are selected in accordance with (4), then setting $\eta = 0$ will result in an efficiency cost of zero. In this special case, the marginal utility weights are invariant across income groups so that (2) would be satisfied at $Q = Q^*$ with the required fee equaling t^*. This outcome is represented by point A in Figure 4 where η is plotted on the horizontal axis and the associated efficiency cost is shown on the vertical axis. As η increases the marginal losses imposed by the Q^{th} user on the Q-1 inframarginal users receive lower relative weight (i.e., as η increases, $MU_i(Y)/MU_Q(Y)$ decreases). This causes the weighted $\sum_{i=1}^{Q-1} ML_i(Q)$ schedule to fall as η increases, so that (2) will be satisfied at higher levels of use with smaller user fees being required and larger efficiency costs being incurred. Accordingly, associated with each value of η is an implied efficiency cost, a cost that varies directly with the magnitude of the constant elasticity of the marginal utility function. The equity-efficiency (E-E) frontier shown in Figure 4 shows the combinations of efficiency costs and η that are generated by varying η from 0 to 1.

Adherence to the traditional efficiency decision rule (1) and the associated user fee of t^* would result in an equity-efficiency outcome shown by point A. Assuming the constituency served by the facility values both its efficient and equitable use, the resulting level of social welfare can be illustrated by indifference curve U_0. Rationing the use of the facility through a reservation system,

[5] This specification of the marginal utility of income weights was used by Feldstein in his seminal article on distributive equity and optimal taxation [3]. In addition, this functional form can be effectively used to describe the federal income taxation policy of giving preferential treatment to lower income individuals. Letting t(Y) be the taxation rate for a family with taxable income Y, regression analysis yields the following:

$$\ln(1 - t(Y)) = \underset{(42.31)}{1.17} - \underset{(48.43)}{0.135} \ln Y$$

$$R^2 = .982 \qquad N = 45$$

For this purpose, then, distributive equity considerations resulted in a value of 0.135 being specified for η in treating differential income levels.

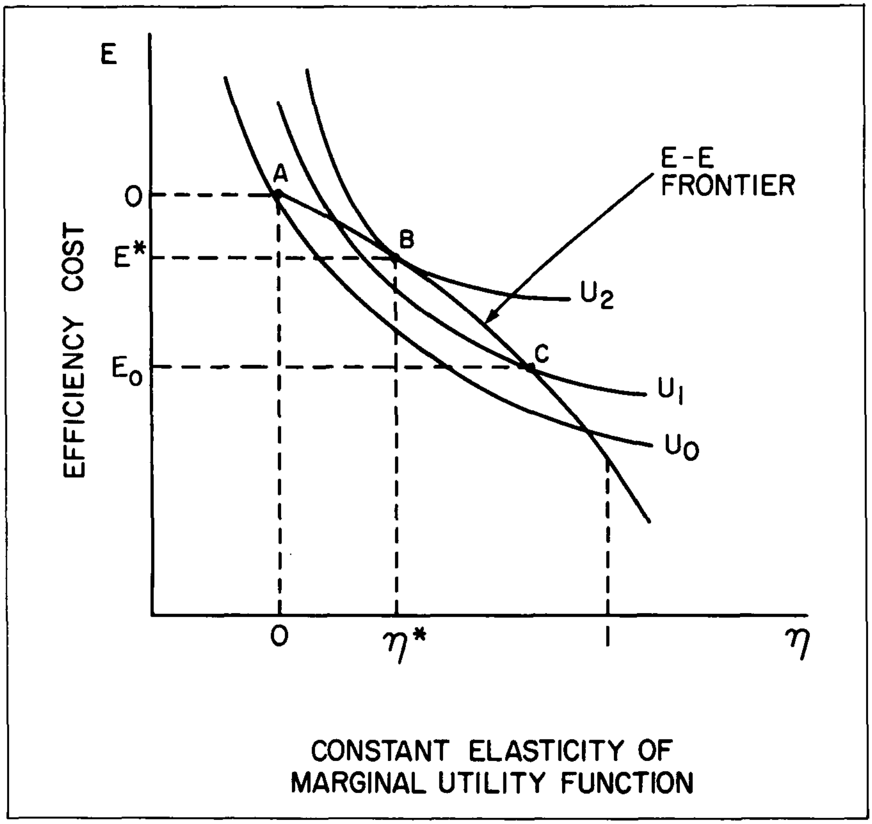

Figure 4. The equity-efficiency frontier and decision making.

on the other hand, may incur sizeable efficiency costs, say E_0. If society values the equity advantages of this approach highly, the equity-efficiency outcome associated with this rationing policy could be preferred ($U_1 > U_0$).[6] The use of socially efficient user fees attempts to explicitly identify an optimum combination of the magnitude and distribution of net benefits by adjusting charges for income characteristics. In many applications, depending upon the tastes and preferences of the affected community, society will be best served by trading some unweighted net benefits ($E^* > O$) for some preferential treatment of lower income users ($\eta^* > O$).

[6] For comparative purposes, equity judgments resulting in the same efficiency cost are treated as analytically identical. That is, the use of MU(Y) weights with $\eta = \eta_0$ and the use of a reservation system are both associated with point C in Figure 4 since an efficiency cost of E_0 results from either policy.

POLICY IMPLICATIONS

The traditional analysis of rationing a fixed-capacity facility subject to congestion externalities can be markedly improved by extending the benefit-cost evaluation to the consideration of weighted net benefits. Several improvements result. First, generation of the E-E frontier eliminates the either-or policy dilemma posed by traditional rationing policies. By using socially efficient user fees, equity gains can be traded for efficiency costs in a systematic and explicit fashion. Second, additional information is provided about the use of a conventional user fee or reservation system to allocate the use of the facility. That is, the resulting opportunity cost of these policies in terms of foregone unweighted net benefits or treatment of preferred groups is made evident. Third, the extended analysis shows that efficacious resource management will require determining an optimal mix of equity and efficiency outcomes, not the single-minded advocation of one goal over the other.

The effectiveness of multiple objective planning can be increased by explicitly determining the equity and efficiency implications of alternative resource policies. This determination requires a willingness to consider the allocative significance of resource proposals based on competing value judgments. Weighted benefit-cost analysis, coupled with sensitivity analysis of weight specification, provides an effective tool for this purpose.

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