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EVALUATING BENEFITS OF ENVIRONMENTAL RESOURCES WITH SPECIAL APPLICATION TO THE HELLS CANYON

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I

In recent years there has been a growing sensitivity on the part of the public at large to assaults on the quality of the environment. The general public is coming to share the views formerly almost the exclusive property of the natural history buffs; namely, members of such organizations as the Audubon Society, Sierra Club and Wilderness Society and their kindred spirits. By and large, the movers and shakers of the industrial society—all active participants in the game of physical and economic development—tended to regard such views as whimsical, if they even took note of them. This is readily understandable given the orientation of the construction related engineering fraternity. In retrospect, however, it seems unusual following the work of Pigou only a half century ago, that economists were so late in recognizing the economic implications of the relationships of which biologists and ecologists were so acutely aware. Pigouvian welfare economics provided the conceptual basis for appreciating the opportunity costs of unanticipated side effects—or effects whose incidence could be shifted to someone other than the contracting parties in the market. The adverse side effects of various activities for environmental quality could and should have been incorporated in the economic calculus had the economics fraternity been alert to the fact that this was a field meriting their serious consideration. Accordingly, how might economics be employed in analysis of a practical problem in which a potential assault on the environment is likely to have an adverse irreversible consequence?

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The environment may provide a flow of economic services either of a production variety (capacity to assimilate industrial wastes) or consumption variety (stimuli which enhance aesthetic or recreational enjoyment). Modern industry and transportation give rise to the major demands on the environment's assimilative capacity, and when they exceed it, environmental quality deterioration results. Extractive industries, including land and water resource development, are responsible for the most serious impact on the visual character of the landscape, and by modifying the ecological characteristics, reduce the biological diversity typically found in the natural environment. It is with this latter issue or with the opportunity costs of landscape modification, that this paper will be primarily concerned.

Landscape alteration if undertaken in particularly scenic areas, or in an area which fosters rare ecosystems, may result in an irreversible adverse effect. In other words, it may affect a non-reproducible gift of nature, and if there are no close substitutes for the services the area in question provides, such irreproducible environmental resources are irreplaceable assets. Herein lies the nub of the analytic problem when an environmental resource can be devoted to two alternative incompatible purposes. One purpose, associated with extractive activities, would convert the natural environment into intermediate products to satisfy the requirements of industrial raw materials used in production of final consumption goods. The other purpose involves the retention of the natural environment for the provision of a flow of services which enter directly into the utility function of final consumers. The effects of one, while providing economic services, result in an action with an irreversible consequence, having a dynamic opportunity cost—*i.e.*, a cost which grows over time. The other, because it does not destroy or alter non-reproducible assets, does not foreclose any future options which are not reflected in the opportunity returns foregone from the precluded alternative use of the area. This point deserves further elaboration.

Extractive industry outputs are both a) producible goods or services and b) intermediate goods or services for which substitutes typically exist. Advances in technology, accordingly, may affect a broad range of substitute sources equally able to supply intermediate goods and services utilized in producing a final consumption good. For example, a consumer of a kilowatt hour of electrical energy receives the same utility from its consumption irrespective of whether it is produced by falling water, combustion of fossil fuel or nuclear reaction. There is a high degree of substitutability among hydro-electric and steam electric power in the production of electrical energy, and between fossil fuel and nuclear materials in the production of such energy from a steam plant. Technological advances within either of these tends to reduce their costs over time. Consider, however, electricity used in final consumption by the householder for illumination, or motive power for household appliances. Potential substitutes are not as convenient; for example, a kerosene lamp is not a very close substitute for an incandescent light, nor a gas engine for an electric motor in a vacuum cleaner.

The alternative use of a natural area by contrast represents a) a non-producible service and b) a service which enters directly into the utility function of individuals as a final consumption good. If the area in question is characterized by some rare attributes giving rise to aesthetic, recreation enhancing stimuli, the range of substitutes may be both narrow and grossly imperfect. In short, were the area devoted to an incompatible alternative purpose there would be a very much more limited opportunity for substitutes to satisfy the preferences to which such services cater. Moreover, since such environmental resources are not producible, growth in demand for their services cannot be met by an increase in their supply.

We can perceive in these circumstances a differential incidence in the effects of technological progress on the value of the natural area in question depending on the purpose to which it shall be devoted. If it is destined to serve some extractive or developmental purpose, it will produce intermediate goods. Any increase in the demand for such intermediate goods can be met by increasing the production, or supply, of such goods. And if advances in technology among any of the substitute intermediate goods is sufficient to permit increased output at falling supply price,[1] the value of the service flow of the area if devoted to a developmental objective, will diminish with the growth of productive efficiency over time. On the other hand, if the natural area is retained in its natural state, the services it provides in its natural state are non-producible. Accordingly, irrespective of growth in demand, the supply cannot be increased. Moreover, since gains in productive efficiency which technology provides are not relevant to non-produced goods or services, technological advance will not avail. Accordingly, an increase in the demand for non-augmentable services for which there are no close substitutes will increase its scarcity value, and hence the value of the irreplaceable

1. *See* H. Barnett & C. Morse, Scarcity and Growth, The Economics of Natural Resource Availability (1963), *especially* ch. 8, for the historical trend in supply price of natural resource commodities.

asset which provides these non-augmentable services, relative to the value of the area when devoted to the alternative developmental purpose.

II

We can summarize and extend the general discussion of Section I. Consider the annual benefit a given asset provides,

$$b_t = b_o(1 + \alpha)^t$$

where

b_t = benefit of any year t
b_o = benefit of the base year
α = the annual rate of change in b

Assume now that the demand for the service the asset provides increases. Then,

$$b_t \gtrless b_o \quad \text{as} \quad \alpha \gtrless 0$$

If α is a positive rate of change the annual benefit will change over time as our b_t function in the diagram below:

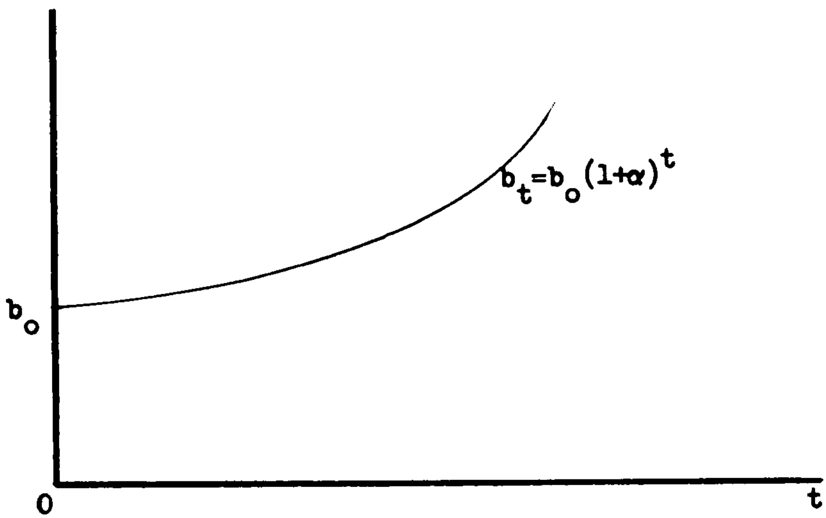

Figure 1 ($\alpha > 0$)

If α is equal to zero, there will be no change in the value of annual benefits. Thus in Figure 2, b_t remains constant.

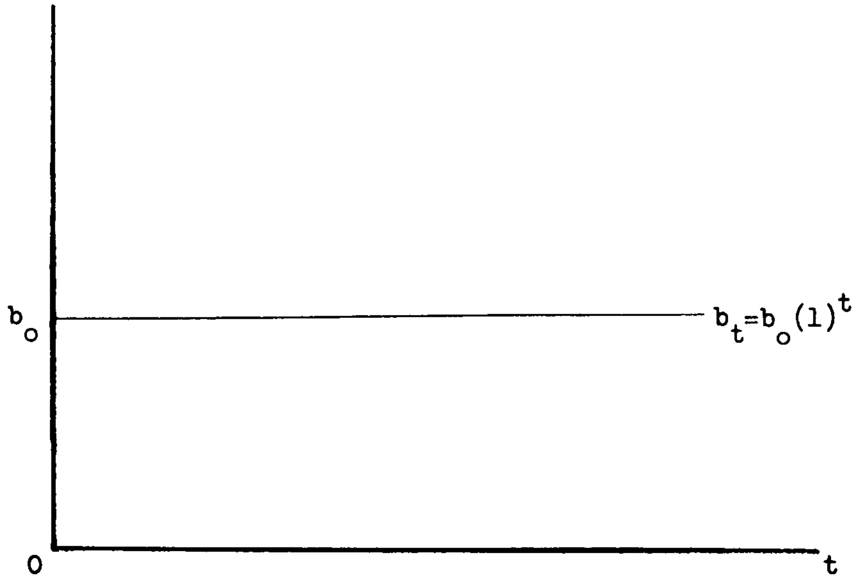

Figure 2 ($\alpha = 0$)

If α is negative the annual benefits of the asset will decline over time as shown in Figure 3.

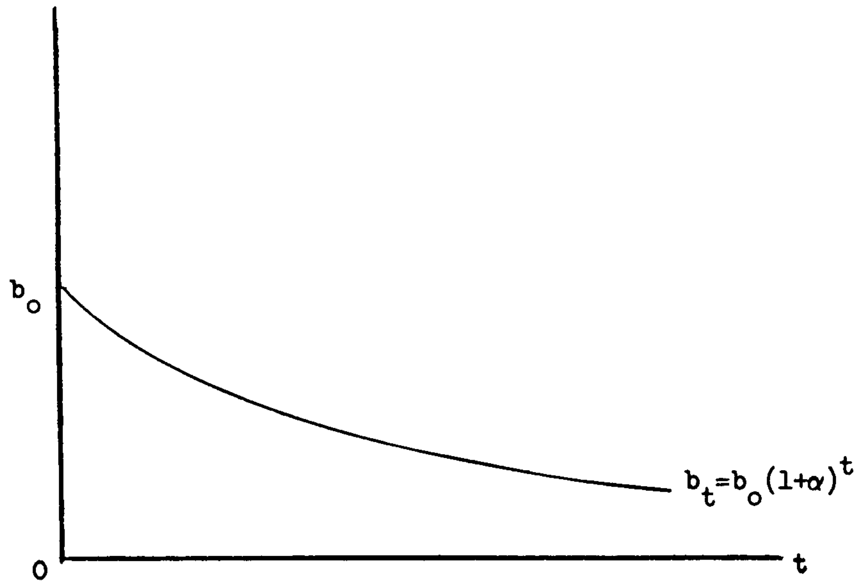

Figure 3 ($\alpha < 0$)

Case 1 illustrated by Figure 1 represents the annual value of the services of a non-reproducible asset the demand for the services of which are increasing. Case 3 illustrated by Figure 3 represents the case of the producible asset, when the supply prices of close substitutes fall over time in response to advances in productive technique.

Now if we wish to get some measure of the value of the asset itself, rather than the annual benefit of its service flow, we need the discounted sum of the benefit stream. Accordingly the value of the asset is the present value PV of the discounted annual benefits

$$PV = \sum_{t=1}^{T} \frac{b_o(1+\alpha)^t}{(1+i)^t}$$

where

PV = present value

T = terminal year to which the discounted annual benefits are summed

i = rate of discount.

To reflect the depreciating annual benefits when $\alpha < 0$, we will represent $(1+\alpha)$ by $\frac{1}{(1+r)}$. Accordingly, we can contrast the effects on the present value of an asset between case (1) where an irreplaceable asset is preserved and case (3) where it has been devoted to an irreversibly incompatible developmental purpose. For the preservation case we have

$$PV_p = \sum_{t=1}^{T} \frac{b_o(1+\alpha)^t}{(1+i)^t}$$

and for development

$$PV_d = \sum_{t=1}^{T} \frac{b_o(1)^t}{(1+i)^t(1+r)^t}$$

We know from application of optimal control theory that the time horizon T should be given by the year in which the discounted value of the terminal year's benefit falls to zero.[2] Accordingly, in the preservation case, if $\alpha \geq i$, the time horizon is infinite so long as the asset is protected against destruction (e.g., from over intensive use). But even if the rate of growth in annual benefits is less than the annual rate of discount ($\alpha < i$) so long as α is a positive value ($i-\alpha < i$), the time horizon, while not infinite, is longer than one given by a constant annual benefit discounted at the rate i. In short, a

2. Paper presented by Anthony Fisher, The Operational Use of Natural Areas, Western Economics Association Meetings (Aug. 30-Sep. 1, 1970).

growth rate will act to reduce the effect of discounting by the extent to which the rate of growth of annual benefits exceeds zero.

Consider next the case of converting the natural area either through development or extractive activities.

$$PV_d = \sum_{t=1}^{T} \frac{b_o (1)^t}{(1+r)^t (1+i)^t}$$

In this case not only does the discount rate take its full effect but the effect is compounded by the rate at which the annual benefits are eroded through technological advance among produced substitute sources of intermediate goods. Accordingly, the time horizon in this case will be shorter in proportion to the differential in the effective rate at which the annual benefits are discounted.

In considering any decision involving irreversible adverse effects, it is mandatory to look beyond the initial year's benefits under the two alternatives because of the differential incidence of technological progress and the resulting difference in the relevant time horizons for estimating the corresponding present values. The present value of the environmental resource under the two incompatible purposes it may serve is dependent in addition to the initial year's benefits (b_O), also on the rate of change in benefits over time (α) and on the discount rate (i). The latter two (α and i) are necessary to define the terminal year (T) for summing the discounted annual benefits.

III

How then do we obtain α (or r, where $\alpha < 0$), i, and b_O? Of course, α, r and b_O depend on the circumstances of each case where there is a choice to be made between incompatible development or preservation alternatives, and these must be investigated as part of any evaluation process. The discount rate, however, is a more general parameter related to the opportunity cost of capital generally,[3] and would be obtained by reference to the general state of the economy.[4] Any one of a number of cases involving potential assaults on

3. *See* Seagraves, *More on the Social Rate of Discount,* 84 Q.J. Econ. 430 (1970), for a summary statement of the probable concensus on the range of values which the discount rate may take.

4. We know from the works of O. Eckstein, Water Resources Development, The Economics of Project Evaluation 99, and Steiner, *Choosing Among Alternative Public Investments in the Water Resource Field,* 49 Am. Econ. Rev. 893 (1959), that for formal correctness there will be a social time preference with which the discounting is done that may differ from the opportunity cost rate. However, the opportunity cost sector's as well as the development project's return streams must be discounted by the same social rate—which, for practical purposes approximates discounting with the rate reflected in the opportunity cost of capital.

the visual and biotic environment may be chosen to illustrate the way in which one might go about estimating the particular values. For our purpose, we will use the problem involving the current controversy over the Hells Canyon of the Snake River—whether to develop for hydroelectric purposes or preserve for inclusion in the Wild and Scenic Rivers System—as the special case for illustration.[5]

The problem at issue relates to the fact that the Hells Canyon has unique geomorphologic characteristics which qualify it for addition to the system of natural areas provided under the Wild and Scenic Rivers Act. At the same time, because of the narrowness of the gorge, the steepness of its walls and the volume of stream flow in this reach of the Snake River, the Canyon provides exceptionally fine sites for hydroelectric development. Thus we find a case where the preservation of such a natural environment is likely to have opportunity costs (and vice versa) so that a meaningful economic issue is posed. Moreover we know that there have been advances in technology in the production of energy from alternative non-hydroelectric sources. We also are justified in regarding the Canyon and its environment as not producible by man, hence if the natural environment is altered by development, a decision with an adverse irreversible consequence for an irreproducible asset will have been taken. We need to evaluate each of the mutually exclusive alternatives to determine the present value of their respective benefits, which represent opportunity costs for the alternative.

A. The Developmental Alternative

Consider now the proposed hydroelectric development. The technology of a given time is incorporated in the dam and powerhouse in such a facility at the time it is built, and will fix the costs of generation over the economic life of the facility. The annual benefit, on the other hand, being governed by the cost of the most economical alternative source,[6] does not remain constant over the life of the

5. *Hearings Before the F.P.C., in the Matter of Pacific Northwest Power Company and Washington Public Power Supply System*, Projects Nos. 2243 & 2273 [hereinafter cited as *F.P.C. Hearings*].

6. The benefit from hydroelectric development can be represented as below:

$b_d = B_d - C_d - B_a + C_a$

where:

b_d = net benefit from hydroelectric development
B_d = gross benefit from hydroelectric development
C_d = cost of hydroelectric production
B_a = gross benefit from alternative source of power
C_a = cost of alternative source of power production

Since the alternative to the hydroelectric development, for comparative purposes, is designed to produce identical services, $B_d = B_a$. Accordingly, the net benefit, b_a is equal to hydroelectric facility. The cost of thermal power generation has declined progressively over the past half century, and by about 4.5 percent per year over the past two decades. Part of this was due to the decrease in capital investment per kilowatt of capacity (capacity costs); part was due to the increased efficiency in the utilization of fuel (energy costs). If the life of the alternative source is shorter than that of the hydroelectric facility (and the real cost of the more technologically advanced replacement capacity is lower than at the time of hydroproject construction), then the capacity benefits of the hydroelectric facility will be lower upon the hypothesized retirement and replacement of the thermal alternative with which the hydro is being compared.

The effects of advances in technology of thermal generation, however, have not been restricted to the capacity component of costs. Gains in thermal efficiency have occurred and also have implications for the valuation of the hydro facility. As the plant factor on technologically advanced new plants will be higher than the system load factor, the difference in factors represents the percentage of a new plant's capacity which can generate "economy energy" to displace energy produced by the most uneconomic plant in the system. A given plant, when new, will enter the system at, say, 90 percent plant factor. As it ages, it will be used a progressively smaller proportion of the time so that by the twentieth year it may operate only 30 percent of the time.[7] Accordingly, the relevant energy cost will be that given by the weighted average of today's and tomorrow's technology, with the costs reflecting future technology figuring progressively more significantly as the relevant annual energy costs until the original thermal alternative is replaced (say, in the thirtieth year). At that time both the energy and capacity values would be governed by the state of technology of the thirty-first, not the original, year. Thereafter, the capacity value will remain constant from the thirty-first to the terminal year (which could be from thirty-five to fifty years depending on the configuration of rates of technological change and discount rates). The formal model is presented as Appendix A.

B. The Preservation Alternative

Consider next the preservation alternative. The value of any

$C_a - C_d$, or the resource savings, if any, from development of the hydroelectric resource. *See* Steiner, *The Role of Alternative Cost in Project Design and Selection,* 79 Q.J. Econ. 417, 421-22 (1965).

7. F.P.C. studies indicate that historically, for fossil fuel plants, the plant factor has fallen to 20% by the twentieth year. For computational convenience I use an initial plant factor of 90%, a 3% point per year factor decay to give us a plant factor of 30% in the twentieth year and retirement in the thirtieth year.

quantity of service consumed per unit time is measured by the area under the demand schedule. When the facility providing the service is a reusable, non-depreciating asset, such as a natural environment protected against destruction or degradation, the value of benefits is the area under the demand curve for each time period the natural area is used. If time is given the customary value of one year, the gross benefit of the natural area would be approximated by the sum of discounted annual benefits. The present value can then be compared with the capital investment (if any), the present value of annual operating costs (if any) and also the opportunity costs, or the net present value of the most economical alternative use precluded by retention of the area for uses compatible with existing environmental conditions in the Canyon.[8]

If the demand for the services of the area grow, a point may be reached beyond which the use of the area by one more individual per unit time either results in a lessening of the utility obtained by others due to the well known congestion phenomenon, or to the destruction of the environmental characteristics of the area. In the case of Hells Canyon, it must be recognized that a recreational capacity, for example, will be reached in time and if a given quality of recreational experience is to be maintained, resort to rationing is imperative.

Growth in the demand for services of the area and a capacity constraint introduces some complexity in analysis. First, income and population change through time, reflecting increases in the demand

8. To establish the consistency in the treatment of the developmental and preservation benefits, we represent the benefit derivation model for the preservation alternative as below:

$b_p = B_p - C_p - B'_a + C'_a$

where:

b_p = net benefit from preservation alternative
B_p = gross benefit from preservation alternative
C_p = cost of providing services from the preservation alternative
B'_a = gross recreation benefit from alternative to preservation
C'_a = cost of providing recreational services alternative to the services provided by the Canyon preserved in present condition.

Now, since the Canyon in an undeveloped state is a gift of nature, the costs (other than opportunity costs accounted for in b_d, *supra* note 6) are zero.

We have;

$b_p = B_p - B'_a + C'_a$

However, since we look to produced assets services as alternatives, and assuming free entry into the recreational services industry, we would expect that the leisure formerly consumed in Hells Canyon facilities would be distributed across the alternatives impinging at the margins. Now, since the benefits at the margin under the circumstances would equal the costs at the margin, B'_a and C'_a would be equal. Accordingly, $b_p = B_p$, which corresponds to the results presented in Table IV, § IV *infra.* This assumes, of course, that there exist no appreciable alternatives similar to the Hells Canyon which could accommodate the demand otherwise met by Hells Canyon.

for services of the Canyon, other things remaining equal. But as the supply is not augmentable, the Canyon being an irreproducible asset, we would expect the annual value of the services to grow as the demand curve in conventional analysis shifts outward, reflecting income and population growth. Such growth in annual value of services must be incorporated in the benefit estimation procedure. Secondly, the capacity constraint adds to the complexity in quantitative evaluation, since it sets a limit on the range over which the quantity demanded can be summed without adjustment.

The analytic and computational models developed to deal with this problem are presented in Appendix B.[9] Accordingly, only a rough schematic of the argument is presented below to indicate the rationale underlying the analysis. In Figure 4 we have the conven-

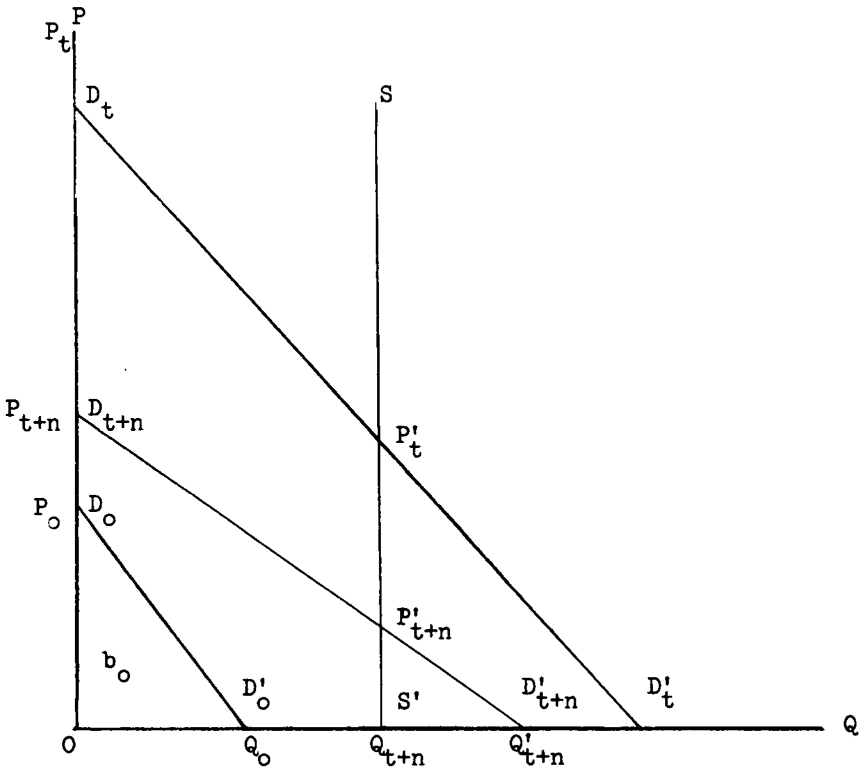

Figure 4

9. The interested reader may also consult *Technical Note on Estimating the Present Value of a Non-Depreciating, Non-Reproducible Asset with Increasing Annual Benefits Over Time, F.P.C. Hearings, supra* note 5, at Exhibit No. R-667. The argument is further developed in J. Krutilla, C. Cicchetti, A. Freeman & C. Russel, *Observations on the Economics of Irreplaceable Assets,* Environmental Quality Analysis: Research Studies in Social Sciences (A. Kneese & B. Bower eds., forthcoming) [hereinafter cited as Krutilla].

tional price-quantity axis with D_OD_O' the initial period's demand for the recreational services of Hells Canyon. The vertical SS' represents the non-augmentable supply of services of a *given and fixed quality.* In the initial period there is an excess supply, relative to quantity demanded at zero price, and all who seek the services can be accommodated without utility-diminishing congestion externalities. The annual benefit, therefore, would be equal to the total area (b_O) under the initial period's demand curve D_OD_O'. At some time (t + n) the quantity demanded at zero price exceeds the supply, and to retain quality of the service, rationing must be in force.[10] P_{t+n}, P'_{t+n} represents the schedule which a discriminating monopolist could exact as prices, and the total value under the demand curve D_{t+n}, D'_{t+n}, less that represented by the area under the excess demand portion of the schedule (Q_{t+n}, P'_{t+n}, Q'_{t+n}) represents the annual value for the transaction period given the schedules in question.

A simplifying assumption would be that the demand curve shifts out uniformly from the origin, but investigation suggests this assumption should be modified in the interest of greater realism. As a result, taking what evidence we have on the growth in demand for primitive area recreation generally, and the income elasticity and related phenomena for this type service,[11] we relate the shift in the demand function intercept of the price axis (r_y) to the projected growth in real per capita income. We relate the shift along the horizontal, or quantity, axis intercept to the recorded rate of growth in quantity demanded at zero price (γ) dampened to eventually equal only the rate of growth of population. The resulting shifts will produce demand schedules with both changing slopes and also, given the capacity constraint, changing geometric shapes in the relevant areas under the demand curve. These observations are illustrated in the three time-dated demand schedules in Figure 4.

So much for the outline of the argument and computational models. One additional point merits mention before the quantitative results of analysis are presented. Ideally one would wish to develop a demand schedule for each of the several recreational activities which one could anticipate being enjoyed in the area, *e.g.*, fishing, white-water boating, hunting, backpacking, etc. These demand functions could be estimated whether jointly where merited, or independently, by procedures developed in the evolving literature in recreational demand estimation.[12] Were information available, the behavior of

10. We assume price as a rationing device to exclude demand in excess of Q_{t+n}.

11. Krutilla testimony, *F.P.C. Hearings, supra* note 5, at R-5859-69.

12. For a survey of the literature as of 1967, *see* Burton & Fulcher, *Measurement of Recreational Benefits–A Survey,* J. Econ. Studies (1967); *also* R. Smith, *The Evaluation of Recreational Benefits: Some Problems of the Clawson Method,* Studies of Recreational

such schedules for each separable activity could be projected and the specific present worths computed, taking into account congestion costs, if any, of two or more distinctly different recreational activities indulged in simultaneously by different individuals. The research effort required was substantially beyond the scope of the present study. Instead, a "composite demand function" was contrived so that, as implied in Figure 1, only one shifting demand schedule was employed as a proxy for the combination of independent and related demand functions. Moreover, since no less time would have been required to estimate such a hybrid function than to estimate the individual demand functions, an alternative strategem was adopted. The question was asked, in effect, "What would the benefit from preservation need to be to be equal to, or exceed, the developmental benefit?"

Since the time profile of annual benefits from the two alternatives will differ, one depreciating while the other appreciating with time, the present value of the two non-uniform time streams needs to be computed. Perhaps a more useful perspective can be gained, however, by determining what the initial year's benefit from preservation would need to be, growing at the rate (α) implied by the annual shifts in the composite demand function, to be equal to the present value of the developmental alternative. This would be desirable, for example, if we were not able to obtain any adequate estimates of the initial year's preservation benefits and would need to have some threshold value on which to base a judgment. We could obtain such a threshold value by computing the present value of a dollar's worth of initial year's benefits growing at the rate of α and discounted appropriately for time. Such a present value computation, divided into the present value of the hydro-electric development, would yield the estimate of the initial year's preservation benefit which would be required to justify economically, the preservation alternative; i.e., would be equal to the opportunity cost of foregoing the development. The results of performing such an exercise are given in section IV.

IV

In this section we display the results obtained when the asymmetry in the implications of technological progress is considered explicitly in the evaluation of the two incompatible alternative uses of Hells Canyon.

Demand No. 5, Faculty of Commerce and Social Science Discussion Paper Series B., University of Birmingham; *and* C. Cicchetti, J. Seneca & P. Davidson, The Demand and Supply of Outdoor Recreation (Bureau of Economic Research, Rutgers–The State University, New Brunswick, N.J., 1969).

In the case of introducing technological advance in thermal alternatives to hydro-electric development, the quantitative results will depend on investment per *kilowatt capacity*[13] of the alternative thermal source, itself partly depending on the interest rate. In addition, the results will depend on the cost per *kilowatt hour* of thermal *energy.*[14] Finally, the rate of advance in technical efficiency itself enters into the calculation of the difference between the results obtained when technological advance is, and when it is not, introduced explicitly into the analysis. For our purposes, we have relied on construction cost data provided by a Federal Power Commission staff witness;[15] have used opportunity cost of capital of 9 percent, but with estimates provided alternatively using 8 percent and 10 percent for purposes of sensitivity analyses; rates of technological progress of between 3 percent and 5 percent per year, to bracket what is believed to be the relevant range;[16] and energy costs, again supplied by FPC staff witnesses, of 0.98 mills per kilowatt hour in the early stage, ranging to 1.28 mills per kilowatt hour in the later period of analysis.[17] The adjustment factors for introducing the influence of technological change into the analysis are given in Table I following.

Accordingly, for any given interest rate (and hence capacity cost per kilowatt); rate of technological change, taken to represent the likely rate in future; and energy costs in mills per kilowatt hour; the generation costs estimated by traditional methods (sum of capacity and energy costs) would be divided by the values given in Table I to obtain the adjusted alternative costs—hence, the benefits of the proposed hydro-electric development. While the gross benefits of hydro appear to be only marginally affected; *i.e.*, reduced by only five to ten percent, the net benefits and hence present value of the site for hydro development, are reduced by a half. This result followed from the fact that the thermal alternative to hydro was a close cost competitor; thus a five to ten percent change in gross benefits had a large effect on the net value of the developmental alternative.[18]

In connection with the preservation alternative's composite benefit computations, the present value of a dollar's worth of initial year's benefit is a function of both the rate of growth in annual

13. A fixed cost for capacity to meet peak requirements.

14. A variable cost for energy, which is at a load factor less than 100% capacity.

15. *F.P.C. Hearings, supra* note 5, at Exhibit No. R-54-B.

16. Data on technological change computed from Steam Station Cost Surveys (Electrical World, 1950-1968).

17. *F.P.C. Hearings, supra* note 5, at Exhibit No. R-107-B.

18. *See F.P.C. Hearings, supra* note 5, at R-5842-43 and Exhibits Nos. R-669, R-669-A, R-671 & R-671-A, for a detailed explanation of the derivation of benefits using technological change model, and for effect on net value.

Table 1
OVERSTATEMENT OF HYDRO-ELECTRIC CAPACITY AND ENERGY VALUES BY NEGLECTING INFLUENCE OF TECHNOLOGICAL ADVANCES

Discount Rate/ Year	Technological Advance Rate/Year	Conventionally Estimated Benefits as a Percentage of Actual Benefits When Adjusted for Influence of Technological Advance, for Various Capacity and Energy Costs			
i =	r_t =	$/KW Capacity	Percent at 0.98 mills per kwh	Percent at 1.22 mills per kwh	Percent at 1.28 mills per kwh
	0.03		107.4	107.9	108.0
0.08	0.04	$27.43	109.0	109.6	109.7
	0.05		110.2	110.9	111.1
	0.03		105.9	106.4	106.5
0.09	0.04	$30.08	107.2	107.7	107.8
	0.05		108.2	108.8	108.9
	0.03		104.8	105.1	105.2
0.10	0.04	$32.89	105.8	106.2	106.3
	0.05		106.5	107.1	107.2

benefits, α, and the discount rate, i. But annual benefits grow at a non-uniform rate over time depending on the values which are taken by γ, r_y, k and m. (See Table II for definition of terms.) Since k represents the "recreational capacity" which is given by the capacity of the area to accommodate recreation seekers without eroding the quality of the recreational experience, the k's are a function of the γ's. The particular values taken, *i.e.*, γ of 10 percent and k of 20 years, with alternative assumptions for purposes of sensitivity analyses, were chosen for reasons given elsewhere.[19] A discount rate of 9 percent, with alternatives of 8 and 10 percent was the result of independent study.[20] The selection of the value for m of 50 years, with alternative assumptions of 40 and 60, was governed by both the rate of growth of general demand for wilderness or primitive area recreation, and the estimated "saturation level" for such recreational participation for the population as a whole. Finally, the range of values for r_y was taken from what we know about the income elasticity of demand for this kind of recreation activity[21] and growth in per capita income over the past two or three decades.

The results of our "preferred" values, with alternatives given for changes in assumptions are displayed in Table II. These present value computations can next be divided into the net present value of the water resource development project—*i.e.*, the hydro-electric power

19. *Id.* at R-5864-66 & R-5872.

20. *Hearings on Economic Analysis of Public Investment Decision: Interest Rate Policy and Discounting Analysis Before a Subcomm. on Economy of Government of the Joint Economic Committee,* 90th Cong., 2nd Sess. (1968). *See also* Seagraves, *supra* note 3.

21. C. Cicchetti, J. Seneca & P. Davidson, *The Demand and Supply of Outdoor Recreation* (Dep't of Interior, 1969); Krutilla, *supra* note 9.

Table II

PRESENT VALUE OF ONE DOLLAR'S WORTH OF INITIAL YEAR'S PRESERVATION BENEFITS GROWING AT α

$i = 8\%$, $m = 50$ years

r_y	$\gamma = 7.5\%$, $k = 25$ years	$\gamma = 10\%$, $k = 20$ years	$\gamma = 12.5\%$, $k = 15$ years
0.04	$ 134.08	$ 169.86	$ 173.90
0.05	211.72	263.49	262.12
0.06	385.10	467.30	449.00

$i = 9\%$, $m = 50$ years

r_y	$\gamma = 7.5\%$, $k = 25$ years	$\gamma = 10\%$, $k = 20$ years	$\gamma = 12.5\%$, $k = 15$ years
0.04	$ 93.67	$ 120.07	$ 125.89
0.05	136.12	172.35	176.25
0.06	214.76	267.10	264.49

$i = 10\%$, $m = 50$ years

r_y	$\gamma = 7.5\%$, $k = 25$ years	$\gamma = 10\%$, $k = 20$ years	$\gamma = 12.5\%$, $k = 15$ years
0.04	$ 69.28	$ 89.45	$ 95.71
0.05	95.15	121.91	127.68
0.06	138.17	174.85	178.66

Where:
- i = discount rate
- r_y = annual rate of growth of price per user day
- γ = annual rate of growth of quantity demanded at given price
- k = number of years after initial year in which carrying capacity constraint becomes effective
- m = number of years after initial year in which gamma falls to rate of growth of population.

value, along with incidental flood control and related multi-purpose development benefits—to yield the initial year's preservation benefit which (growing at α and discounted at i) would have a present value equal to the present value of development. The corresponding initial year's preservation benefits are displayed in Table III.

Now, what does this tell us which the traditional analysis of comparable situations requiring the allocation of "gifts of nature" between two incompatible alternatives does not?

Table III

Initial Year's Preservation Benefits (Growing at the Rate α) Required in order to have Present Value Equal to Development

i = 8%, m = 50 years, r_t = 0.04, PV_d = $18,540,000*

r_y	γ = 7.5%, k = 25 years	γ = 10%, k = 20 years	γ = 12.5%, k = 15 years
0.04	$ 138,276	$ 109,149	$ 106,613
0.05	87,568	70,363	70,731
0.06	48,143	39,674	41,292

i = 9%, m = 50 years, r_t = 0.04, PV_d = $13,809,000*

r_y	γ = 7.5%, k = 25 years	γ = 10%, k = 20 years	γ = 12.5%, k = 15 years
0.04	$ 147,422	$ 115,008	$ 109,691
0.05	101,447	80,122	78,336
0.06	64,300	51,700	52,210

i = 10%, m = 50 years, r_t = 0.04, PV_d = $9,861,000*

r_y	γ = 7.5%, k = 25 years	γ = 10%, k = 20 years	γ = 12.5%, k = 15 years
0.04	$ 142,335	$ 110,240	$ 103,030
0.05	103,626	80,888	77,232
0.06	71,369	56,397	55,194

* Source: Exhibit No. R-671.

Where:
- i = discount rate
- r_y = annual rate of growth in price per user day
- γ = annual rate of growth of quantity demanded at given price
- k = number of years following initial year upon which carrying capacity constraint becomes effective
- m = number of years after initial year upon which gamma falls to rate of growth of population
- PV_d = Present Value of Development
- r_t = annual rate of technological progress

Let us take for illustration, subject later to sensitivity analysis, the computed initial year's preservation benefit corresponding to i of 9 percent, r_t of 0.04, γ of 10 percent and k of 20 years, m of 50 years and r_y of 0.05; namely, $80,122. Is this a threshold value we might expect to be equaled or exceeded by the first year of the hydro-electric project would otherwise go into operation? In many cases we would have only the sketchiest information and would have to make such a comparison on a judgmental basis. In the case of Hells Canyon, we obtained rather better information and shall return to the matter subsequently. But for now, we have the sum of $80,000 as the benchmark figure which we feel is necessary to justify, on economic grounds, allocation of the resource to uses compatible with retention of the area in its present condition. This sum of $80,000 compares with the sum of $2.9 million, which represents the "levelized" annual benefit from the hydro-electric development, when neither adjustments for technological progress have been made in hydro-electric power value computations, nor any site value (i.e., present value of opportunity returns foreclosed by altering the present use of the Canyon) is imputed to costs. Typically then, the question would be raised whether or not the preservation value is equal to or greater than the $2.9 million average annual benefits from development.

Let us consider the readily quantifiable benefits from the existing uses of the Canyon. These are based on studies conducted by the Oregon and Idaho State's Fish and Game Departments, in collaboration with the U.S. Forest Service, and are displayed along with our imputation of values per user day in Table IV below. From Table IV one could argue, for example, that the preservation benefits shown are roughly only a third as large as would be required based on traditional analysis of similar cases. By introducing the differential incidence of technological progress on the mutually exclusive alternatives for Hells Canyon, we have quite a different conclusion. The initial year's preservation benefit, subject to re-evaluation on the basis of sensitivity tests, appears to be an order of magnitude larger than it needs to be to have a present value equal to or exceeding that of the development alternative. Thus introducing differential incidence of technological progress affects the conclusions in a significant way.

What about the sensitivity of these conclusions to the particular values the variables used in our two simulation models are given? Sensitivity tests can be performed with the data contained in Tables II and III, along with additional information available from computer runs performed. Some of these checks are displayed in Table V.

Given the estimated user days and imputed value per user day, it follows that the conclusions regarding the relative economic values of the two alternatives are not sensitive within a reasonable range, to

Table IV

ILLUSTRATIVE OPPORTUNITY COSTS OF ALTERING FREE FLOWING RIVER AND RELATED CANYON ENVIRONMENT BY DEVELOPMENT OF HIGH MOUNTAIN SHEEP

Quantified losses	Recreation Days 1969[2]	Visitor Days 1969[3]	Visitor Days 1976
Stream Based Recreation:[1]			
Total of boat counter survey	18,755	28,132	51,000
Upstream of Salmon-Snake confluence	9,622	14,439	26,000
Non-boat access:			
Imnaha-Dug Bar	9,678	14,517	26,000
Pittsburgh Landing	9,643	14,464	26,000
Hells Canyon Downstream:			
Boat anglers	2,472	1,000	1,800
Bank anglers	9,559	2,333	4,000
Total stream use above Salmon River	40,974 plus[4]	46,753 plus[4]	84,000 at $ 5.00/day = $420,000
Hunting, Canyon Area[5]			
Big Game	7,050	7,050	7,000 at 25.00/day = 175,000
Upland Birds	1,110	1,110	1,000 at 10.00/day = 10,000
Diminished value of hunting experience[6]	18,000	18,000	29,000 at 10.00/day = 290,000

Total Quantified losses . . . . $895,000 ± 25%

Unevaluated Losses:

A. Unmitigated anadromous fish losses outside impact area.
B. Unmitigated resident fish losses:
1) Stream fishing downstream from High Mountain Sheep.
C. Option Value of rare geomorphological-biological-ecological phenomena.
D. Others.

1. Source: *An Evaluation of Recreational Use on the Snake River in the High Mountain Sheep Impact Area,* Survey by Oregon State Game Commission and Idaho State Fish and Game Department in cooperation with U.S. Forest Service, Report dated January 1970 and Memorandum, W.B. Hall, Liaison Officer, Wallowa-Whitman National Forest, dated January 20, 1970.
2. "Recreation Days" corresponds to definition as per *Supplement #1, Senate Document No. 97;* namely, an individual engaging in recreation for any "reasonable portion of a day." In this particular study, time involved must be minimum of one hour, as per letter, from Monte Richards, Coordinator, Basin Investigations, Idaho Fish and Game Department.
3. "Visitor Day" corresponds to the President's Recreational Advisory Council (now, Environmental Quality Council) *Coordination Bulletin No. 6* definition of a visitor day as a twelve hour day. Operationally, the total number of hours, divided by twelve, will give the appropriate "visitor day" estimate.
4. Not included in the survey were scenic flights, not trail use via Saddle Creek and Battle Creek Trails. Thus, estimates given represent an under-reporting of an unevaluated amount.
5. "Middle Snake River Study, Idaho, Oregon and Washington" Joint Report of the Bureau of Commercial Fisheries and Bureau of Sports Fisheries and Wildlife in *Department of the Interior Resource Study of the Middle Snake,* Tables 10, and 11.
6. The figure 18,000 hunter days is based on Witness Pitney's estimate of 15,000 big game hunter days on the Oregon side, and estimated 10,000 hunter days on the Idaho side (provided in letter from Monte Richards, Coordinator, Idaho Basin Investigations, Idaho Fish and Game Department, dated February 13, 1970), for a total of 25,000 hunter days (excluding small game, i.e., principally upland birds) in the Canyon area, less estimated losses of 7,000 hunter days. This provides the estimated 18,000 hunter day, 1969 total, which growing at estimated 5 percent per year for deer hunting and 9 percent per year for elk hunting would total 29,000 hunter days by 1976.

Table V

SENSITIVITY OF ESTIMATED INITIAL YEAR'S REQUIRED PRESERVATION BENEFITS TO CHANGES IN VALUE OF VARIABLES AND PARAMETERS (at i - 9%)

Variable	Variation in Variable From	To	Percent Change	Percent Change in Preservation Benefit
r_y	0.04	0.05	25	39-49
r_t	0.04	0.05	25	25
k*	20 yrs.	25 yrs.	25	30-40
γ	10%	12.5%	25	-4 to +7
m	40 yrs.	50 yrs.	25	3

*The 25 percent change in years before capacity is reached translates into a 40 percent change in carrying capacity at the growth rate of 10% used here.

the particular values chosen, for the variables and parameters used in the two computational models.

There is need, however, for another set of tests when geometric growth rates are being used. We might regard these as "plausibility analyses." They would test, for example, the plausibility of the ratio of the implicit price to the projected per capita income in the terminal year, to ensure credibility of the results. Similarly for the plausibility of the ratio of the terminal year's preservation benefit, say, to the GNP in the terminal year. The year at which the growth rate in quantity of wilderness type outdoor recreation services demanded falls to the rate of growth of the population must also be checked to ensure that the implicit population participation rate is reasonable. Such tests were performed in connection with the Hells Canyon case in order to avoid problems which otherwise would stem from use of unbounded estimates.

Finally, since the readily observed initial year's benefits appeared to be in excess of the minimum which would be required to have such preservation benefits equal to or exceeded in present worth the developmental benefits, the analysis was terminated. Following Weisbrod,[22] however, while an excess of benefits as estimated above from the preservation of an irreplaceable asset is sufficient to justify its retention on economic grounds, it need not be necessary. Two reasons can be given; one relates to the problem of option value, *i.e.*, the value of retaining an effective option when faced with a decision having irreversible consequences, which was not included in the above estimation procedure. The second relates to the particular measure of consumer surplus used in estimating the benefit; *i.e.*, whether the aggregate willingness of users to pay for the services of the Canyon preserved in its present condition—the measure implied in the analysis above—or the aggregate sum which would need to be provided the users of the Canyon otherwise retained in its present condition, to have them voluntarily relinquish their claims to its use. These measures are not identical except in a special case, and the one used above represents only a lower bound estimate. Since these considerations were not essential to the analysis, *i.e.*, the lower bound estimate exceeded the required total, we mention them only in passing.[23]

V

In this paper we have reported on a study directed toward aiding a resource allocation decision involving amenity aspects of the environ-

22. Weisbrod, *Collective Consumption Services of Individual Consumption Goods*, 78 Q.J. Econ. 471 (1964).

23. *See* Krutilla, *supra* note 9, for a more extended treatment of these considerations.

ment. The problem contains a number of considerations which are either novel, or at least considered only for the first time in any quantitative sense. Perhaps the reason the heretofore elusive elements were considered at all in this case relates to the Federal Power Commission's interest in responding to the Supreme Court's directive to give the visual and related aesthetic aspects of the environment explicit consideration in reaching a decision as to whether the remaining portion of the Hells Canyon should or should not be licensed for development.[24]

As a first venture in this area there is no reason to pretend that it represents the ultimate development of analytic means for dealing with problems of this sort. The sensitivity tests have revealed in fact, that while the conclusions would not be reversed were the assumed values of the parameters to be changed within any reasonable range in the Hells Canyon case, there is evidence that in cases where the results of analysis would fall within a narrower range, the particular values which the parameters were assumed to take could be critical to the outcome. Accordingly, there is need to investigate, both theoretically and empirically, a number of problems to further sharpen the analysis for cases in the future where the problem of choice would be less clear cut.

Among problems rating high priority would be the further investigation of the asymmetric effects of technological progress particularly as they influence the value of the r_y parameter (note Table V). Another problem demanding additional attention is the problem of developing an operational measure for optimal recreation capacity for such low density recreational resources. Now while an estimate of option value was not necessary in the Hells Canyon case, the results in its absence being sufficient to justify retaining an option when faced with a decision having an irreversible result might be the critical element on which the decision would turn. Accordingly, additional work in the area of developing operational measures for the value of such options ranks among the priority research tasks to aid making similar decisions in this general area in the future. Finally, since the Supreme Court in recent decisions appears to have granted the aggrieved public "standing" in court when common property resources are being used to the detriment of the general public, the measure of the damages stemming from a change in the natural environment deserve careful consideration. Typical of traditional benefit-cost analysis, as well as in the measure employed in the study reported on above, has been an estimate of the willingness of beneficiaries of the unaltered environment to pay the prospective de-

24. Udall v. F.P.C., 387 U.S. 428 (1967).

veloper to dissuade him from modifying the status quo. With the standing accorded the public in such cases the nature of the measure changes. It now becomes the amount which the party proposing to alter the environment must pay the aggrieved public to justly compensate it for losses it suffers in altering the environment. As this measure (price equivalent measure of consumer surplus) is normally greater than the conventional measure used (price compensating measure of consumer surplus) the difference in measures employed may become critical in future cases where the outcome from traditional analysis is insufficient to support preservation of the existing environment in unaltered form. This problem merits joint economic and legal investigation in order that consistency in legal and economic doctrine be achieved and methods of measurement consistent with this be developed for application in future cases of the nature reported on in this paper.

APPENDIX A

Over the first 30-year period, taken as the useful life of a thermal facility, let PVC_t represent the present value of annual costs per kilowatt of the thermal alternative in year t:

$$PVC_1 = C_1 + E(8760F)$$

$$PVC_2 = \left\{C_1 + \left[E\ 8760(F - k)\right] + \frac{E}{(1+r)}(8760k)\right\}\left(\frac{1}{(1+i)}\right)$$

$$\vdots$$

$$PVC_n = \left\{C_1 + E\left[8760(F - (n-1)k)\right] + \frac{E}{(1+r)^{n-1}}\left[8760(n-1)k\right]\right\}\left(\frac{1}{1+i}\right)^{n-1}$$

for $1 < n < 30$

where C_1 = Capacity Cost/KW/yr during first 30-year period
E = Energy Cost/KWh
F = The plant factor; (.90)
k = a constant representing the time decay of the plant factor (.03)
i = the discount rate
r = the annual rate of technological progress

Writing out the n^{th} term yields:

$$PVC_n = \frac{C_I}{(1+i)^{n-1}} + \frac{8760EF}{(1+i)^{n-1}} - \frac{8760Ek(n-1)}{(1+i)^{n-1}} + \frac{8760Ek(n-1)}{\left[(1+r)(1+i)\right]^{n-1}}$$

These terms can be summed individually using standard formulas for geometric progressions[1] and then factored to form:

$$PVC_{1,\ldots,30} = \sum_{n=1}^{30} PVC_n = (C_I + 8760EF)\left[\frac{1-a^{30}}{1 - a}\right] - \frac{8760Ek}{i}\left\{\frac{1-a^{29}}{1 - a} - 29a^{29}\right\} + \frac{8760Ek}{(1+r)(1+i)-1}\left\{\frac{1-b^{29}}{1 - b} - 29b^{29}\right\}$$

where $a = \left(\frac{1}{1+i}\right)$

$b = \frac{1}{(1+r)(1+i)}$

Over years 31, . . . , 50 the cost expressions are similar except that we are dealing with only a 20-year additional period and all terms thus get discounted by a factor of $\left(\frac{1}{1+i}\right)^{30}$. Hence, using similar

1. *See* Chemical Rubber Publishing Co., CRC Standard Mathematical Tables 357 (12th ed. 1961).

formulas for the sum of geometric series the present value of annual costs per kilowatt from this latter period is determined to be:

$$PVC_{31,\ldots,50} = \sum_{n=31}^{50} PVC_n = \left(\frac{1}{1+i}\right)^{30} \left\{ (C_{II} + 8760E'F) \left[\frac{1-a^{20}}{1-a}\right] - \frac{8760E'k}{i}\left[\frac{1-a^{19}}{1-a} - 19a^{19}\right] + \frac{8760E'k}{(1+r)(1+i)-1}\left[\frac{1-b^{19}}{1-b} - 19b^{19}\right]\right\}$$

where $C_{II} = \dfrac{C_I}{(1+r)^{30}}$

$E' = \dfrac{E}{(1+r)^{30}}$

The overall present value is:

$PVC_{1,\ldots,50} = PVC_1 + \ldots + PVC_{30} + PVC_{31} + \ldots + PVC_{50}$

Traditional analyses are based essentially on the model given below.

$$K = \sum_{n=1}^{50} \frac{[C_I + E(8760F)]}{(1+i)^{n-1}}$$ or, which is equivalent,

$$= [C_I + E(8760F)] \left[\frac{1-a^{50}}{1-a}\right]$$ to be consistent with previous notation.

The adjustment factors in Table 1, Section IV are obtained as follows:

$$K / PVC_{1,\ldots,50}$$

APPENDIX B–THE BENEFIT ESTIMATION MODEL FOR THE PRESERVATION CASE

by Charles J. Cicchetti

Let:

b_o = \$1.00 of initial year's benefits

P_o = initial vertical axis intercepts (see Figure I below)

Q_o = initial horizontal axis intercept

$D_oD'_o$ = initial year's composite computational demand schedule

r_y = rate of growth in vertical component of shift, related to the increase in per capita income, assuming a constant (income-price) elasticity $\frac{\Delta P_H}{P_H} \cdot \frac{Y}{\Delta Y} \Big| Q=Q_o$

γ = the historical rate of growth in the quantity demanded for P=0; i.e., horizontal component of demand shift at zero price. γ is constant up until capacity (year k).

k = the year the area reaches recreational carrying capacity

d = the rate of decay of γ after year k which brings the rate of change in horizontal component of demand shift to rate of growth of population

m = the year in which the rate of the horizontal component of demand shift equals the rate of growth of population

i = rate of discount.

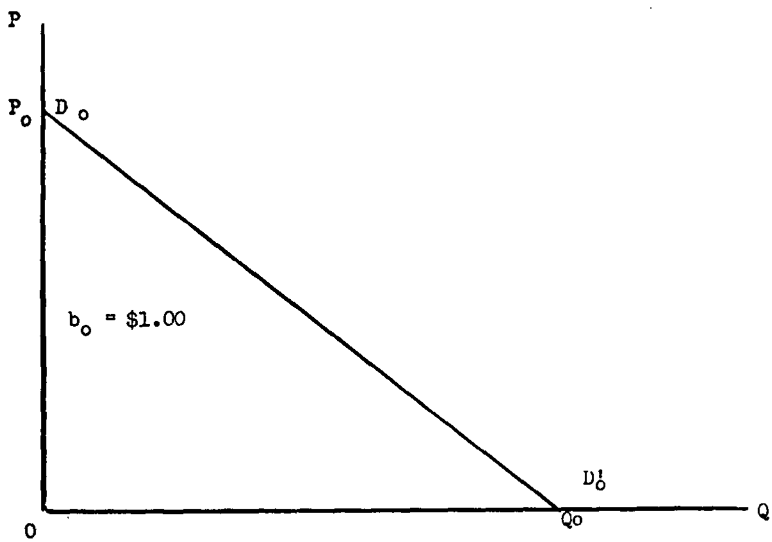

Figure I. Demand Curve in the Initial Year

Equations

$$P_t = (1 + r_y)^t \ P_o$$

$$Q_t = (1 + \gamma\ )^t \ Q_o \quad \text{for } t \leq k$$

$$Q_t = Q_{t-1}\ (1 + \gamma_t) \quad \text{for } t > k$$

where $\gamma_t = \gamma(1 + d)^{t-k}$

and $d = \left[\frac{\gamma \text{ population}}{\gamma}\right]^{\frac{1}{m-k}} -1.$

$$PV_b^{\ o} = \sum_{t=1}^{\infty} \frac{b_t}{(1+i)^t}$$

$$b_t = \frac{1}{2} P_t\ Q_t \quad \text{for } t \leq k$$

i.e., the area under the composite computational demand schedule $D_t\ D'_t$

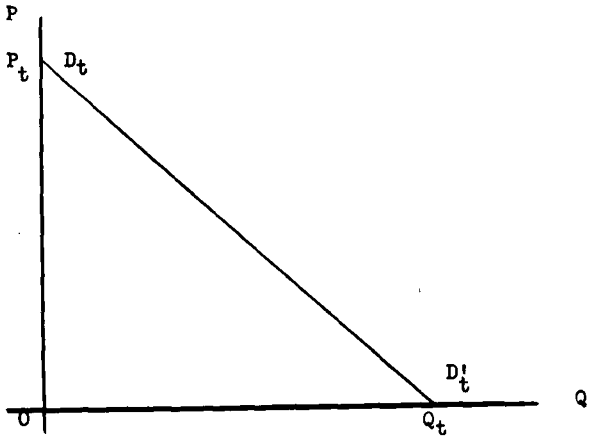

Figure II. Demand Curve in Year $t \leq k$

$$b_t = \frac{1}{2} P_t\ Q_t - \frac{1}{2} P^*_t\ Q^*_t \quad \text{for } t > k$$

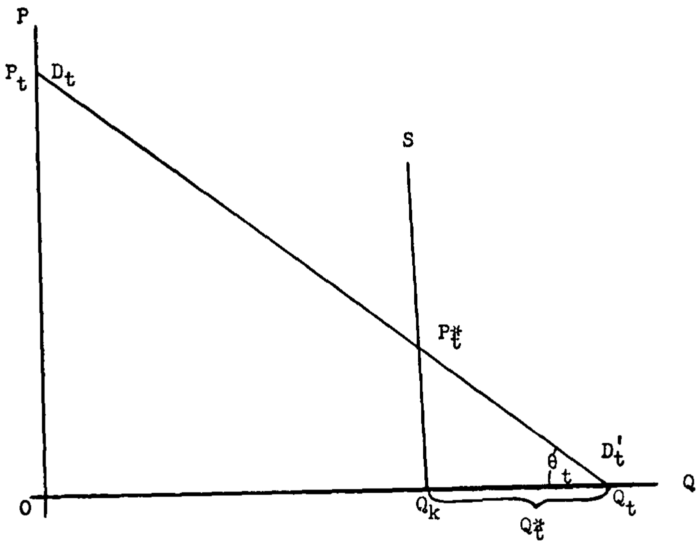

Figure III. Demand Curve in Year t > k

where $\frac{P_t^*}{Q_t^*} = \tan \theta_t = \frac{P_t}{Q_t}$

$\therefore \quad P_t^* = Q_t^* \cdot \frac{P_t}{Q_t}$

and $Q_t^* = Q_t - Q_k$

and $b_t = \frac{1}{2} P_t Q_t - \frac{1}{2} (Q_t - Q_k)^2 \frac{P_t}{Q_t}$ for $t > k$

$\therefore \quad PV_b^o = b_t (t \leq k) + b_t (t > k)$, appropriately discounted.

An important parameter of the system is the annual percent increase in benefits. This is derived as follows:

$$b_t = \frac{1}{2} P_t Q_t \quad \text{for } t \leq k$$

$$= \frac{1}{2} (P_o (1+r_y)^t) (Q_o (1+\gamma)^t)$$

$$= \frac{1}{2} P_o Q_o ((1+r_y) (1+\gamma))^t$$

but $1 = \frac{1}{2} P_o Q_o$

$$\therefore \quad b_t = (1+r_y \; \gamma + r_y + \gamma)^t$$

$$\frac{db_t}{dt} = (1+r_y \; \gamma + r_y + \gamma)^t \; \mathrm{Ln} \; (1+r_y \; \gamma + r_y + \gamma)$$

$$\text{annual percent change in benefits} = \frac{\frac{db_t}{dt}}{b_t}$$

$$\therefore \quad \frac{\frac{db_t}{dt}}{b_t} = \frac{(1 + r_y \; \gamma + r_y + \gamma)^t \; \mathrm{Ln} \; (1 + r_y \; \gamma + r_y + \gamma)}{(1 + r_y \; \gamma + r_y + \gamma)^t}$$

$$= \mathrm{Ln} \; (1 + r_y \; \gamma + r_y + \gamma)$$

$$\text{for } t \leq k$$

The rate of change in preservation benefits referred to in section III, α, is identical to this value $\frac{\frac{db_t}{dt}}{b_t}$ when t is less than capacity, but since tastes are expected to change when the Canyon becomes saturated, the rate of change in benefits begins to decline at capacity (k). Accordingly, $\frac{\frac{db_t}{dt}}{b_t} (t \leq k)$ is an upper bound and would exceed the α discussed in section III for the life of the Canyon.

Finally, the slope of the initial composite computational demand schedule (the area under which is equal to unity) may be varied and the effect measured, since:

$$P = a + sQ$$

$$\frac{P_o \cdot Q_o}{2} = 1$$

and $P_o = P$ when $Q=0$

$Q_o = Q$ when $P=0$

$$\therefore \quad P = P_o + sQ$$

$$s = \frac{P_o}{Q_o}$$

$$sQ_o = P_o$$

$$\text{and} \quad P_o Q_o = 2$$

$$s Q_o^{\,2} = 2$$

$$\therefore \quad Q_o = \sqrt{2/s} \text{ and } P_o = s Q_o$$

This last result allows for the calculation of benefits for various initial slopes as well as varying demand shifts and supply constraints, thus completing the general derivation for the computation of benefits through time for linear demand schedules.

By use of this model to calculate the present value of a dollar's worth of initial year's benefits, we can obtain, of course, the initial year's benefits required to justify retaining the Canyon area in its present uses. The latter can be further decomposed by putting the initial year's benefits on an expected value per user basis. That is, if:

U_O = expected number of users in the initial year

B_O = the required initial year's benefits to justify preserving the Canyon in its present condition

B_O/U_O = the expected average user value required to justify preserving the Canyon area in its present type of uses.

Then this further decomposition permits us to observe the number of recreational (and/or other) users, estimate the average price or value per recreation day required, and compare this value or price with what is known about prices paid for similar types of recreational experiences.