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THE OPTIMAL USE OF NATURAL RESOURCES–THE CHOICE BETWEEN PRESERVATION AND DEVELOPMENT*

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ABSTRACT

In recent years modern society finds itself on the horns of a dilemma; on one hand, there exists the desire to preserve natural environment and prevent their rapid exploitation, and on the other hand to achieve rapid development through greater production and consumption. The dilemma is particularly acute with respect to exhaustible natural resources whose rate of replenishment is very slow. The basic question is in fact the allocation of a commodity, whose supply quantity is limited, between two alternative uses; namely, preservation and development. Such allocation, via the market mechanism, is likely to be skewed against the socially optimal amount of preservation.

There are several reasons for this assertion: (1) difficulties with the assessment of the present value of net social benefits from preservation, particularly social benefits which represent dubious concepts such as consumer's surplus and option value and whose social rate of discount is debatable. (2) technological progress. (3) effect of socio-economic and demographic factors on society's future demand for preserved natural environment. These are very important issues since transformation of natural resources from one state to another is irreversible. In fact, it is a problem of intertemporal optimal allocation of natural resources from the standpoint of society's social benefits.

This problem is typical to a large class of problems when current public decisions should be taken with regard to future events. A closed example is the problem of how to allocate land in an urbanized area for the various uses so as to accommodate future differential intensification of land consuming activities.

About a year ago a request was submitted by Israel's only cement company, to renew and extend the company's concession for quarrying raw material in the Carmel Mountains for its "Nesher" plant.

Soon, citizen groups as well as other private citizens organized to voice their objection to the request. The issue revolved around a long-delayed decision

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received by the Ministry of Interior in 1971, to declare the Carmel Mountains as a preserved National Park. Leaving the legal and political issues aside, the controversy represents a typical problem which arises in connection with the rational public decision of resource allocation; particularly with regard to the question of rational resource allocation between preservation and development.

In fact, the example mentioned above belongs to a class of problems with which society's future planning procedures should deal. Another example is the question of how wide should be the right-of-way for transport routes in a newly developed town so as to accommodate future forecasted traffic, or the question of what should be the amount and the location of open spaces in a rapidly growing urban area.[1]

As is demonstrated in economic analysis, in perfectly competitive markets, resources will be allocated in an optimal way among the various competing economic activities by means of the price system. The optimal combination of factor inputs requires that the ratio of their marginal productivities will be equal to the ratio of their prices: $MP_i/MP_j = P_i/P_j$. Thus the the entrepreneur will purchase his factor inputs in accordance with the given price of the factor and its marginal productivity and with respect to other factor inputs, price and productivity, and the production function of the enterprise. The level of production of the enterprise in a competitive system will be the one at which marginal cost is equal to the market price. There are, however, several aspects which may challenge the adequacy of market mechanism as the sole determinant of resource allocation among competing activities. These are the adequacy of the assumption of perfectly competitive markets in reality; the existence of externalities; ownership over the specific resource private or public; the nature of the supply of the resource and its ramifications. These major aspects suggest that in some instances there may exist a divergence between the cost to the enterprise–*private cost*, and the cost to the society–*social cost*. When social and private costs diverge appreciably it is necessary to intervene so as to equate these two costs.

Natural resources and more specifically, natural environment, particularly natural phenomena, are concerned with all of the aspects mentioned above. To begin with, one may classify natural environment as a *public good* to differentiate it from a *private good*; that is, one person's consumption does not diminish the quantity available for another individual. A good example is a scenic view (commodity $Z\ell$), which can be viewed indiscriminatly by each member of the society $z_{i\ell} = Z\ell$. A private good, on the other hand, is allocated among individuals who consumed fully the good, $\Sigma_i x_{ij} = X_j$. The main problem with a public good is that the good is available to all members of the society no

[1] These particular problems are currently being investigated by the author as part of a large research project financed by the Ford Foundation (Research No. 020-111). Preliminary results of these investigations will be reported in a forthcoming working paper.

matter whether an individual uses, or chooses to pay for it or not. Thus, it is extremely difficult to estimate the social benefit which may be derived from a public good such as the preserved natural environment.

Nevertheless and particularly in view of the great pressure which has been exerted in recent years on the development of natural environment, a group of economists began tackling this basic question: What is the social value of the preserved natural environment?

There are several unique characteristics to the natural environment which call for careful and thorough analysis. Natural resources can be classified into two major groups: (1) *Replenishable* resources such as fish, timber, water etc. (2) *Nonreplenishable* resources such as minerals, natural environment etc. The latter suggests that supply is permanently and perfectly inelastic. Thus, any quantity which is being diverted and transformed from natural state to developed state reduces permanently the amount of natural resources available. This is all the more so in view of the *irreversibility* which characterises the transformation process, that is, once transformed it is virtually impossible (at all cost) to reverse the process. The latter aspect differentiates markedly natural environment services from other consumption goods whose rate of production was influenced, to a large extent, by *technological progresses.* Several studies have, in recent years, demonstrated that the residual growth in output, after allowance for growth explained by the increase in factor inputs like labor, capital and material inputs, is due primarily to technological progress (see Figure 1).

The fact that the supply of the natural environment is limited permanently, and is perfectly inelastic, suggests that the decision concerning the allocation of natural environment for development should take into consideration the future ramifications of the present decision. Moreover, natural environment particularly natural phenomenon, such as the Carmel Mountains, do not have a *close substitute* as far as terrain topography, geomorphology–rock formation, vegetation and wild life are concerned; particularly no *spatial substitution* as a recreational area for the present and future residents of the Haifa metropolitan region.[2] The supply of this natural environment cannot be increased, irrespective of growth in demand, because of the irreproducibility of environmental resources.

With the natural rate of population growth, the rise in standard of living and the migration of population between regions, we should expect to witness an increasing pressure to convert natural environment to build-up areas. The pressure will be felt most strongly in and around rapidly growing urbanized areas. Along with the rapid demand of land consumption for habitation in certain locations we should expect to witness an increase in the rate of demand

[2] This latter aspect reinforces our contention in the opening remarks of this paper that quantities and location of open spaces in an urbanized area are a very important decision variable in land use allocation. This point will become even more critical in the following discussion concerning future demand.

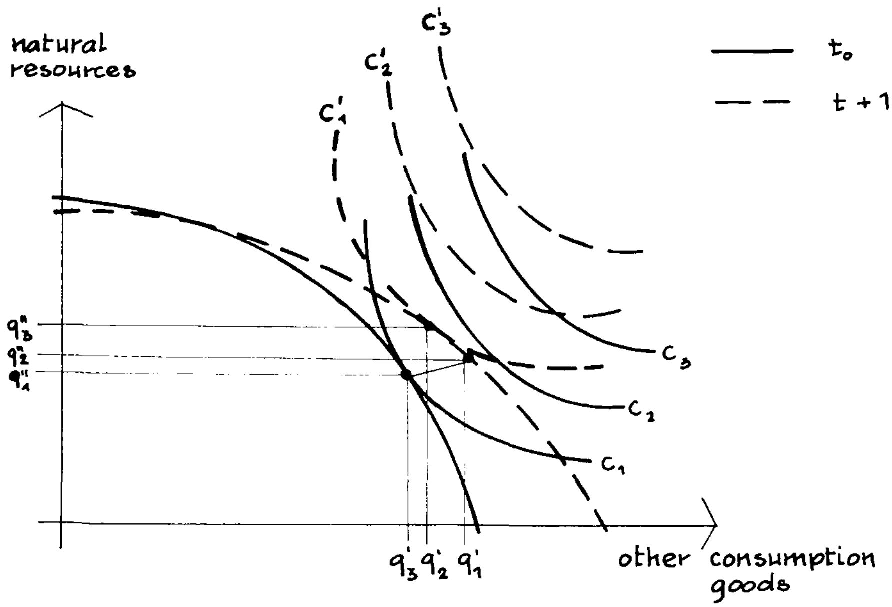

Figure 1

for raw material such as minerals, mining, and other natural resources. Although, as we pointed out, a respectable source of output growth will continue to be due to technological progress, an additional demand for factor inputs will persist in order to meet the growing demand for consumption goods. In short, environmental preservation is *not compatible* with population growth and a rising standard of living which are accompanied by an increasing demand for consumption goods (see Figure 1).

Thus, society is faced with the problem of determining the most efficient allocation of environmental resources. It is implicit from the discussion presented above that given a fixed amount of (divisible) productive resources, the enlargement of any one output level must involve the curtailment of another output level since these are two mutually exclusive events. In order to determine the socially optimal use of natural environment, it is necessary to evaluate the *opportunity costs* each use entails by comparing the benefits to be derived from a given use with those to be derived from the incompatible alternative uses. The benefits foregone are in effect the opportunity costs and thus should be added to the direct costs involved in the production of the selected use. However, it should be recalled that the allocation decision includes the *time dimension*; that is, the allocation decision should be guided by the present value of the social net benefits expected to be obtained from each alternative use over an appropriately long time horizon. It is therefore an *intertemporal optimization* problem in which the optimal allocation of natural environment over time should be examined. The stream of benefits to be derived from each alternative and incompatible use is liable to change with time in accordance with the elasticities of demand and supply for the respective use. The question of measuring the benefits derived from public good such as natural environment represents many obstacles, some of which were dealt with quite successfully, particularly with respect to the assessment of benefits derived from recreation use.

For lack of any pricing mechansim the benefit derived is estimated through the construction of the supply and demand schedules of recreation use. Since the supply of natural environment is virtually *inelastic* and is permanently decreasing over time we should examine most carefully the changes which are expected to take place with respect to the level of demand. The level of demand will be affected by the rate of population growth, increase in per-capita income, increase in leisure time and greater accessibility to the natural environment (see Figure 2). (Here is another instance where spatial distribution may have an effect on demand level.) Population growth will tend to shift the demand schedule to the right on the horizontal axis (if the socio-economic profile of the added population coincides with that of the socio-economic profile of the existing population); that is, the *elasticity of demand*, (which is the ratio of the percentage change in the quantity demanded to the percentage changes in price) will increase. Higher income, on the other hand, will cause the demand curve to shift on the vertical axis; that is, the elasticity of demand will decrease. If these two factors will counter-act each other, we should expect the demand curve to shift upward in a parallel fashion to the present demand curve such that the elasticity of demand will remain unchanged (see Figure 2).

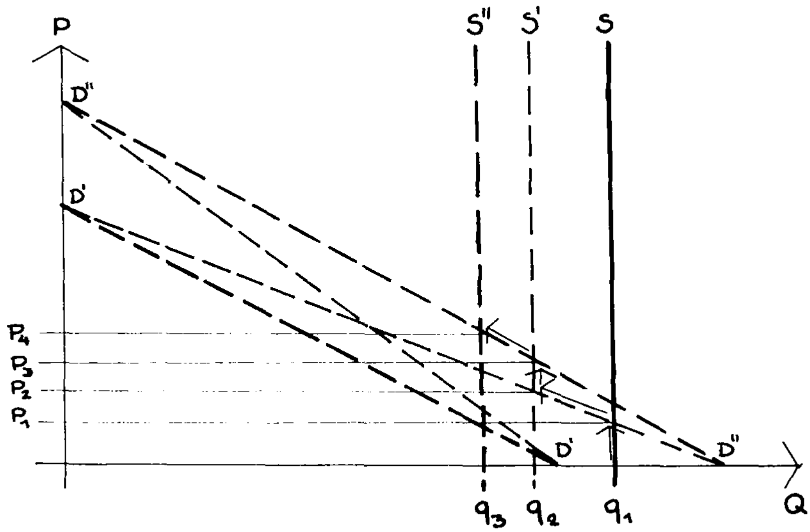

Figure 2

It is quite complicated to estimate the effect of changes in increased leisure time, taste and mobility on the shape of the demand curve, but we shall expect that the net effect of these changes will shift the demand curve. (Mobility will most likely shift the demand curve on the horizontal axis.)

As shown in Figure 1, these changes, particularly the changes in tastes are likely to shift the community indifference curves upward to the left. Consequently, the future socially-optimal allocation of natural environment between preservation and development (which is the tangency point between the upper most convex, community indifference curve and the concave, transformation curve) will be moving upward favoring greater preservation, (this result is being accentuated by the technological progress aspect which shifts the transformation curve to the right on the horizontal axis). (See Figure 1.)

Another aspect which may have an effect on the demand schedule is the capacity limitation of a used natural area. Just as we experience congestion over highway, which considerably reduces the additional demand for the services of the congested highway, we should expect to have an effect on the capacity, however defined, of a certain natural environment area of the level of demand for its services.

The benefits derived from the use of the natural environment can be divided into four components: the first is the *revenue* derived directly from the computation of the amount paid for, and the quantities consumed, that is, the area under the demand curve below the vertical price line which intersects the demand curve. However, this quantity is most often observed in the analysis of natural environment use since not too often are admission changes levied in such areas. On the other hand, some surrogates are being used which represent the direct cost of transportation to and from the site and the indirect costs—of the value of time in reaching and staying at the site.

The second component is the *consumer's surplus* which is being defined as "how much money a consumer would pay for the right to continue to buy at the current price something that he is now buying." This difference between what one actually pays and what he would be willing to pay is represented by the triangular area which is under the demand curve and above the intersection of the price line with the demand curve.

The third component, called the *option value* is more abstract, but very real. Since the use of natural environment is not storable and cannot be purchased prior to consumption, the option demand represents the willingness "to pay something for the option to consume the commodity in the future." Option demand is of no consequence if production can increase at any time to meet the demand of the infrequent and/or future consumers. However, since the expansion of production of natural environment is virtually impossible, it is indeed becoming a factor which is important for efficient resource allocation. In such instances when commodity is purchased infrequently, future demand is uncertain and it is costly or impossible to increase supply—a correction measure is needed for a market optimal resource allocation. Moreover, some natural phenomena are unique and *indivisible*, that is, the act of development however small, will preclude almost totally its use as natural environmental resource. An example is a power station on a dammed river: no matter how small is the power station, it is necessary to dam the river, thus changing its natural state completely. These natural phenomena are not homogeneous; that is, each site is unique with no close substitute: once destroyed, there is no alternative for it.

Finally, the fourth component is the *induced demand*, which is the demand generated by the mere availability and existence of the facility (this notion is analogous to the induced demand for transportation). Induced demand may be materialized upon "discovery" of the availability of the services or may be generated as a result of the first agreeable experience in using the services (better knowledge of the nature of the services and the possible utility which may be derived from its use).

In order to be able to evaluate and determine the present value of the net social returns from natural environment preservation, it is necessary to apply a *social rate of discount* to the stream of benefits to be derived in the future. Obviously, the discount rate will have a very significant effect on the desirability of our preservation decision. There are some very important issues which are related to this aspect. One of which is the extent to which present decisions should take into consideration the anticipated demand for natural environment services fifty or a hundred years hence. Another issue is what should be the time horizon to be considered. One suggested approach is to assume that in order to justify the decision to preserve the land the net benefits of preservation would at least have to equal the net benefits derived from development.

The problem with which we are confronted is to determine the rate of conversion of the natural environment (which is being consumed as a final good) into inputs used in production of consumption goods (i.e. the proposed development) so as to maximize social welfare at each time interval up to the selected time horizon.[3]

Any production, which consumes natural resources in fact entails social costs in that it diminishes the amount of resources available for consumption in all subsequent periods. This foregone consumption enters the dynamic model of Optimal Control where intertemporal aspects appear explicitly as instrumental (control) variables.

To formalize our problem of optimization over time we can define the objective function as the maximization of the Social Welfare Function, SW, through the control of the consumption of natural environment; that is:

[3] This problem is similar in many respects to Samuelson's Intertemporal Price Equilibrium. However, while in his analysis the time horizon extends from one Harvest period to another, our time horizon is practically infinite: that is, no replenishment of natural environment is anticipated in the foreseeable future. Likewise, our demand curve, in particular, is assumed to shift in accordance with the changes which will take place.

$$\max \quad SW = \int_o^\infty P(t)\ell^{(\delta-\rho)t}\, U[c_x(t), c_{y-x}(t), t]\, dt$$

Where P(t) is population at time t which grows at an exponential rate of δ. $P(t) = P(o)\ell^{\delta t}$. The discount rate ρ is a parameter whose value is greater than o, $\rho > o$. The amount of natural environment at t is y(t) and it may be allocated between x and the residual y - x preserved. $U(c_X(t))$ and $U(c_{Y-X}(t))$ are the utility function derived from per-capita consumption of development-consumption goods-and preservation respectively.

The utility function is assumed to be continuously twice differentiable; strictly concave, and increasing. That is:

$$U'(c(t)) > o; \; U''(c(t)) > o$$

The constraints are:

$$\dot{c}_{y-x}(t) = f\,[c_x(t), c_{y-x}(t), t]$$

The rate of change of a state variable, (.) is denote derivative with respect to time,

$$c_{y-x}(to) = c_x \text{ the initial conditions}$$

$$c(t) \geqslant o \text{ for all t, non-negativity}$$

The maximization problem, spelled out in a very general form above, subject to the specified constraints, can be solved using the Maximum Principle of Pontryagin.[4]

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[4] Due to space limitation the complete mathematical specification of the model, including the Hamiltonian function and the auxiliary (dual) variables, will be given elsewhere.

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