Environmental Valuation under Sustainable Development

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Environmentalism has evolved since the 1960's from a concern with the preservation of wilderness in the American experience to a concern over pollution of human habitat throughout the industrialized world. Northern anxiety spread to the loss of tropical rainforests and biodiversity in the South, where environmentalism evolved further in an encounter with indigenous interpretations, conditions, and priorities. By the late 1980's, climate change emerged as a central issue in a now global discourse on the relationship between environment and development. The principle of sustainable development—that current needs are to be met as fully as possible while ensuring that the life opportunities of future generations are undiminished relative to the present—is now widely accepted (World Commission on Environment and Development, 1987).

Throughout this coevolution of public concern, scientific knowledge, and North–South perspectives, economists have generally held that the problem, however framed, reduces to a matter of making markets work better. Societies overexploit natural resources because markets for environmental services are imperfect. If we knew the value of environmental services, we could determine how to allocate their use efficiently. Reflecting this interpretation, international development agencies are addressing sustainability largely through environmental valuation (Mohan Munasinghe and Ernst Lutz, 1991).

In earlier papers we demonstrated that, from an economic perspective, sustainability is a matter of intergenerational equity. The distribution of rights and assets across generations determines whether the efficient allocation of resources sustains human welfare across generations (Howarth and Norgaard, 1990; Howarth, 1991a; Norgaard, 1991). Intergenerational equity is manifested in how we acknowledge rights of future generations, assume responsibilities for our descendants, and otherwise demonstrate our care for those who follow us. If development is not sustainable, it is because the institutions through which the present provides for the future have not evolved in consonance with changes in social and economic structures, technology, and population pressure.

The environmental-valuation literature addressed the interests of future generations through its early association with questions of wilderness preservation. Economists investigated irreversible choices and the contradictions between discounting and being concerned with the distant future (John V. Krutilla and Anthony C. Fisher, 1985). How societies value environmental services is clearly intertwined with whether development is sustainable. In this paper, we illustrate that incorporating environmental values per se in decision-making will not bring about sustainability unless each generation is committed to transferring to the next sufficient natural resources and capital assets to make development sustainable.

The relation between intertemporal allocative efficiency and the intergenerational asset distribution is illustrated in Figure 1. Each point on the utility possibilities frontier represents an efficient allocation of resources, including environmental services, associated with different distributions of endowments and rights between generations. Efficiency puts society on the utility possibilities frontier, but sustainability is a matter of the distribution of assets across generations.

Assume the economy is at the inefficient point A in Figure 1 due to the absence of a market for an environmental service. With environmental valuation, the economy could move to point B on the efficiency frontier. Neither point A nor B is sustainable,

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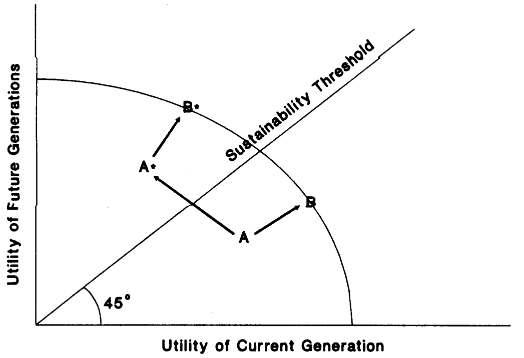

FIGURE 1. THE RELATION BETWEEN INTERTEMPORAL ALLOCATIVE EFFICIENCY AND THE INTERGENERATIONAL ASSET DISTRIBUTION

however, since future generations are left worse-off than the current generation. With an intergenerational redistribution of assets, the economy could shift to point A* which is sustainable but inefficient. From point A*, environmental valuation could move the economy to the sustainable and efficient point B*. Note that the value of environmental services derived from point A* will differ from the value derived at point A. The reason is that the relative prices embodied in the valuation, including interest or discount rates, are different at each point on the frontier. We explore this matter in greater depth using an overlapping-generations model of an economy facing climate change.

I. An Overlapping-Generations Model

The model characterizes a competitive economy with overlapping generations at a sequence of discrete dates $t=1,\dots,T$. A representative firm produces a homogeneous consumption/investment good using capital (K_t), labor (L_t), and self-produced energy (E_t) according to the production function:

$$(1) \qquad F_t = f_t(K_t, L_t, E_t, Q_t) - \alpha E_t.$$

The positive constant α represents the unit cost of energy production. Q_t is a stock of pollutants, "greenhouse gases," determined from past energy use according to the recurrence relation:

$$(2) \qquad Q_{t+1} = \beta(Q_t + \gamma E_t).$$

Some portion of the pollutant stock decays in each period so that $0<\beta<1$. Each unit of energy consumed results in the emission γ units of pollutant. Greenhouse gases have a negative impact on production ($\partial f_t/\partial Q_t < 0$). Production is zero when all inputs are zero, and f_t is differentiable in all its arguments and concave, increasing, and linearly homogeneous in inputs of capital, labor, and energy.

We assume that factor inputs are mobile and savings/investments decisions are managed by the household sector. The firm thus purchases inputs and maximizes profits sequentially in each period. The firm takes the pollutant stock as fixed, ignoring the impacts of current energy use of future production, hence imposing an external cost on future generations through greenhouse-gas emissions. Let the consumption/investment good be the numeraire, let r_t be the interest rate or price of capital services, and let w_t be the wage rate. Assume further that society taxes energy use at the unit rate v_t. The firm's problem is thus to maximize its profit level:

$$(3) \qquad f_t(K_t, L_t, E_t, Q_t) - r_t K_t - w_t L_t - (\alpha + v_t) E_t.$$

This problem yields the first-order conditions:

$$(4) \qquad \begin{aligned} \partial f_t/\partial K_t &= r_t \\ \partial f_t/\partial L_t &= w_t \\ \partial f_t/\partial E_t &= \alpha + v_t \end{aligned}$$

that are necessary and sufficient for the achievement of an interior solution. Profits are zero because the production function is linearly homogeneous.

Consumption and investment behavior are embedded in two generations of consumers/investors, one young and one old, who are alive at each date. We assume that population is constant and that each generation consists of a single representative individual. Let C_{1t} be the consumption of the young at date t while C_{2t} is the consumption of the old. The preferences of the generation born at date t are represented by the utility function $U_t(C_{1t}, C_{2t+1})$, which is differentiable, concave, and increasing.

Young individuals hold the labor stock L_t that they supply inelastically to the production sector. The young receive a net (positive or negative) lump-sum income transfer T_{1t} from society, while the old receive the income transfer T_{2t}. Intergenerational altruism in our model occurs through socially mandated asset transfers. Some might argue that parent–offspring altruism should ensure sustained improvements in the human condition, obviating the need to consider sustainability as an explicit policy criterion. The theoretical literature, however, shows that the welfare of future generations is likely to be a public good to a considerable extent, implying a significant role for collective action in effecting socially desired intergenerational transfers (Stephen A. Marglin, 1963; Howarth and Norgaard, 1991). Individuals clearly cannot provide for the climate of their offspring acting individually.

The young divide their income between consumption and capital investment. The old hold no labor endowments but receive returns on their capital assets. The budget constraints thus may be written

$$(5) \qquad C_{1t} + K_{t+1} = w_t L_t + T_{1t}$$

$$(6) \qquad C_{2t+1} = (1 + r_{t+1}) K_{t+1} + T_{2t+1}.$$

Each generation has perfect foresight concerning future economic conditions. Taking prices and income transfers as given, utility maximization implies the first-order condition:

$$(7) \qquad \frac{\partial U_t / \partial C_{1t}}{\partial U_t / \partial C_{2t+1}} = 1 + r_{t+1}$$

that is necessary and sufficient for an interior solution.

Closing the model requires that the market for the consumption/investment good clears at each date. In addition, there is a set of emissions taxes and income transfers satisfying the balanced budget relation $T_{1t} + T_{2t} = v_t E_t$. The efficient energy tax conforms to that derived using the present-value criterion (Howarth, 1991b):

$$(8) \qquad v_t = -\sum_{i=1}^{T-t} \left(\gamma \beta^i \frac{\partial f_{t+i}}{\partial Q_{t+i}} \prod_{j=1}^{i} \frac{1}{1 + \rho_{t+j}} \right)$$

where ρ_t is the social discount rate at date t. The $\gamma \beta^i$ term measures the marginal increase in the future pollutant stock caused by a unit increase in current energy use, while $\partial f_{t+i} / \partial Q_{t+i}$ is the marginal loss in production caused by the pollutant. The emissions tax is thus set equal to the marginal present-value cost that current energy use imposes on the future economy. Setting the discount rate equal to the rate of interest (i.e., $\rho_t = r_t$), leads to an equilibrium that is Pareto efficient, so that it is impossible to improve the welfare of one generation without leaving another worse off (Howarth, 1991b).

Pareto efficiency, however, does not ensure that consumption or utility is sustained over time. Consider, for example, the equilibria that arise under alternative income transfers for the following version of the model. Suppose that the time horizon approaches infinity and that the production and utility functions are

$$(9) \qquad F_t = (1 - 0.2 Q_t^2)(K_t L_t E_t)^{1/3} - 0.1 E_t$$

$$(10) \qquad U_t = \ln(C_{1t}) + \ln(C_{2t+1}).$$

The initial capital and pollutant stocks are $K_0 = 1$ and $Q_0 = 1$, while each generation's labor endowment is $L_t = 1$. The parameters of the pollutant-stock equation are $\beta = 0.9$ and $\gamma = 1$. Finally, assume that society chooses the set of income transfers to support the optimum that arises under the social welfare function:

$$(11) \qquad W(\delta) = \sum_{t=-1}^{T} \delta^t U_t$$

as a competitive equilibrium. Here δ is a parameter that defines the weight attached to the welfare of future generations relative to the present. We shall focus our attention

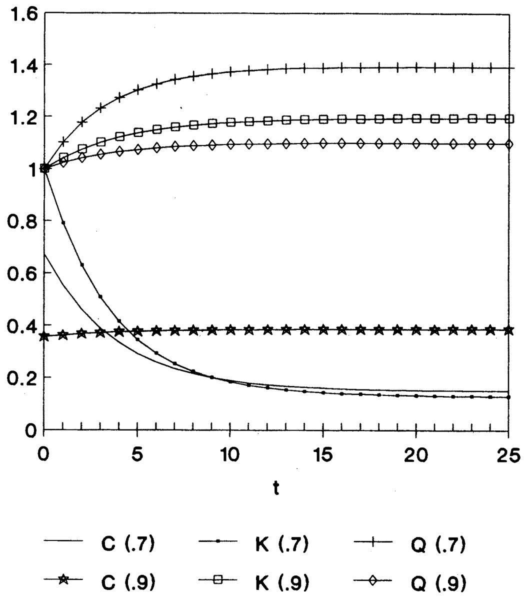

FIGURE 2. VARIATION IN SOCIAL PREFERENCES LEADS TO A SUBSTANTIAL CHANGE IN THE PATH OF THE ECONOMY

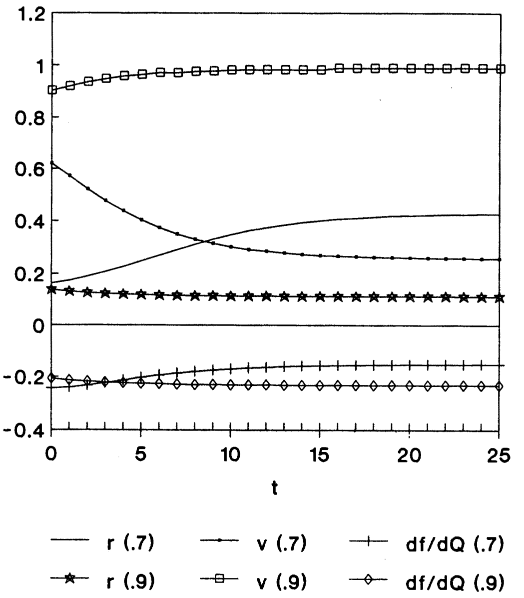

FIGURE 3. THE EFFECT OF THE DISTRIBUTION OF WEALTH BETWEEN PRESENT AND FUTURE GENERATIONS ON THE VALUE OF ENVIRONMENTAL GOODS

on the equilibria that arise for two cases: $\delta = 0.7$ and $\delta = 0.9$.

Figure 2 shows that this ostensibly small variation in social preferences leads to a substantial change in the path of the economy. For $\delta = 0.7$, both total consumption ($C_t = C_{1t} + C_{2t}$) and the capital stock fall precipitously over time, while the pollutant stock grows at a rapid rate before achieving a steady state. (Time subscripts are omitted in the figure. Numbers in parentheses indicate δ values.) For $\delta = 0.9$, consumption rises slowly over time, while the capital stock first rises to support higher output levels. Attaching greater weight to the welfare of future generations implies lower pollutant emissions and hence improved environmental quality. The pollutant stock is thus permanently less for $\delta = 0.9$ than for $\delta = 0.7$.

Figure 3 shows how the distribution of wealth between present and future generations affects the value of environmental goods. As δ is raised from 0.7 to 0.9, the firm's output rises over the long term, exacerbating the marginal impact of the pollution stock on current production ($\partial f_t / \partial Q_t$). Increasing the assets transferred to future generations also lowers the social discount rate (r_t). The net result is that the present value of the marginal environmental damage caused by current energy use, which is equal to the efficient emissions tax, increases substantially.

II. Conclusions

Reasoning from a partial-equilibrium framework, economists have argued that environmental valuation and the incorporation of such values in decision-making is a way of caring for future generations. Reasoning from a general-equilibrium framework, we show that the valuation of environmental services and how society cares for the future are interdependent. Valuation when there is too little caring for the future (i.e., too little asset transfer) will not lead to sustainability. With sufficient caring for the future, environmental valuation yields different results both because the incremental value per period is different (higher in our example) and because interest rates are probably lower under sustainability. Overlapping-generations models facilitate this change in perspective through the provision of discrete generations to which rights can be assigned or assets transferred. Furthermore, with a general-equilibrium model, we discover how interest or discount rates, which reflect the marginal time preference of individuals rather than social concerns over intergenerational equity, vary with asset transfers.

Most importantly, from a general-equilibrium framework we see that the valuation of nonmarket goods and social objectives are intertwined. Economic valuation brings a society closer to its goals by increasing the efficiency of the economy. The economic values of market and nonmarket factors including the rate of interest, however, depend on the social objectives sought.

Acknowledging this complementarity between economic values and social objectives does not solve the moral question of how the rights of future generations and responsibilities of current generations should be defined, nor does it reduce the scientific complexities and uncertainties of the interplay among climate, biodiversity, resource scarcity, and other factors affecting the sustainability of development. Valuation techniques rooted in partial-equilibrium reasoning are still appropriate for small, local issues. The relationships between social goals and valuation identified by the general-equilibrium framework, however, indicate serious conceptual inadequacies in the analyses to date of global issues such as climate change (National Academy of Sciences, 1991; Nordhaus, 1991).

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