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A central question asked by environmental and resource economists is, "what useful economic functions does the environment provide and how are these functions affected by the process of economic-environmental interaction?"(8) A conventional approach and an alternative approach are outlined here. A model of economic-environmental interaction is constructed based on the alternative approach to show how such a method is suitable for analyzing emerging problems of environmental degradation.

Conventional Approaches

Following Hotelling[1] (1931), the conventional approach defines natural resources as those environmental resources that provide economically valuable productive services. This view sees the natural environment solely as a supplier of raw material and energy inputs to the economic process. When a natural resource becomes scarce, its price will rise relative to that of other goods. Therefore, it is the expected threat of future scarcity from over-exploitation and depletion that makes it worthwhile to hold on to certain material and energy-yielding natural resources. This leads one to ask what the ideal rate of depletion is. For nonrenewables it may be optimal to deplete the resource if future technologies and the availability of perfect substitutes make the resource inessential for future production. For renewables, exhaustion may be optimal if the resource is growing at a slow rate, harvesting costs are low, and its value appreciates more slowly than the market rate of interest. This approach is based on the optimistic expectation that markets will automatically determine the optimal rate of exploitation.

Alternative Approaches

An alternative approach recognizes three important functions performed by the environment and by scarce environmental resources:

1) providing useful material and energy inputs for the economic process;
2) assimilating waste by-products generated by the economic process; and
3) providing utility, i.e., yielding services or ecological functions that are essential for supporting the economic system and human welfare, including recreational, health, cultural, scientific, educational and aesthetic services, as well as the maintenance of essential climatic and ecological cycles.

As the environment is used by the human economy, the quality of the environment itself may deteriorate, and this is seen as an economic problem. This view may lead to different criteria for the economic exploitation of environmental resources, as it considers the total economic value provided by all functions of an environmental asset. The absolute effects of ecosystem degradation must be considered, rather than only the relative scarcity effects of the conventional approach.

A Model of Economic-Environmental Interaction

The model presented here builds on a number of studies that emphasize the environmental costs of economic activity. It addresses a situation in which economic-environmental interaction leads not only to increasing relative scarcity of utility-yielding environmental services, but also to the possibility of widespread ecological disruption and disturbances.

In the model a social welfare function is defined based on consumption and on a stock variable that represents environmental quality. It is assumed that over time the capital stock in the economy increases by the difference between output and the sum of three other factors: consumption, resources used for environmental improvement, and capital depreciation. In addition, environmental quality declines over time due to extraction of resources and generation of wastes. It is assumed that the improvements in the environment can never be greater than the deterioration; environmental quality is likely to decline in each period. The existence of a maximum tolerable level of environmental degradation is also assumed, beyond which the economic-environmental system is destabilized.

The planning problem suggested by the model is how best to allocate economic and environmental resources over time, given declining environmental quality and the threat of a future ecological constraint. The model yields:

1) the optimal trade-off between increased consumption and provision of services to improve the environment; and
2) the rule governing the optimal rate of capital accumulation, and thus the optimal rate of growth in the economy.

The model is different from the conventional approach in suggesting that at some point the benefits of capital accumulation and growth (in the form of expanding output) may be outstripped by the costs of such growth in the form of environmental degradation. Determination of the optimal allocation of economic and environmental resources clearly depends upon the relative preferences of individuals, the development of technology, and the resilience and regenerative capacity of the ecosystem.

Wider Implications: Technology, Tastes, and Time

Conventional approaches indicate that technological innovation, substitution and improvements in resource management can help overcome increasing relative scarcity. The model presented here suggests that, with the proper use of technology and environmental management, the rate of environmental degradation can be slowed down appreciably by reducing the inflow of material

and energy from the environment and the outflow of waste. Some of the resource saving approaches that can be applied to economic activity include:

1) factor substitution, e.g., of labor power for energy;
2) reusing scrap and waste materials;
3) increasing efficiency of resource conversion and utilization to obtain the maximum amount of end-use energy and material for production of final goods and services from primary inflows of resources;
4) improving organizational techniques;
5) changing composition of outputs, e.g., from non-durables to durables, or from resource using goods to services; and
6) changing product quality and/or design.

The technology needed to achieve these innovations may already exist. However, such technologies may not be adopted unless new conservation oriented macro-economic policy goals are accepted. In addition to technological improvements, better techniques of resource management, appropriate planning of tourist facilities and conservation areas, and training and dissemination of conservation skills will help as well. When applied to agricultural systems, these techniques may also result in the added advantage of increases in production.

However, resource saving environmental management techniques may not be implemented for a number of reasons. For example, many environmental resources exist outside the gamut of market commodities, so automatic market signals are inappropriate for determining allocation. Moreover, even if external environmental costs of depletion are calculated, there is still no way of accounting for the decay of the ecological process itself, especially since we do not have a clear understanding of the effects of pollutants and resource depletion on ecological systems. In addition, given the First and Second Laws of Thermodynamics, there are limits to how much environmental degradation can be reduced. Finally, there is no way of determining the trade-offs between future consumption and environmental quality, as we do not know the tastes and preferences of future generations.

Notes

1. Harold Hotelling, "The Economics of Exhaustible Resources," in *Journal of Political Economy* 39(2), 137-75 (1931).