ALFSEN, KNUT; TORSTEIN BYE and LORENTS LORENTSEN (1987). *Natural Resource Accounting and Analysis: The Norwegian Experience, 1978--86.* Social and Economic Study 65. Oslo: Central Bureau of Statistics of Norway.

BARTELMUS, PETER; CARSTEN, STAHMER and JAN VAN TONGEREN (1989). *"SNA Framework for Integrated Environmental and Economic Accounting".* Paper presented to the IARIW conference in Lahnstein, West Germany, August 20-25, 1989. A revised version is forthcoming in the Review of Income and Wealth.

DALY, HERMAN (1989). *Sustainable Development: Some Basic Principles.* Processed. World Bank.

EL SERAFY, SALAH (1981). "Absorptive Capacity, the Demand for Revenue, and the Supply of Petroleum". *The Journal of Energy and Development* 7 (1, Autumn): 73–88.

EL SERAFY, SALAH (1990). *"The Environment as Capital".* Paper presented to the Conference on the Ecological Economics of Sustainability, Washington, D.C. (May 21-23).

HICKS, JOHN R. (1946). *Value and Capital.* 2nd. ed. Oxford: Oxford University Press.

KEYNES, JOHN MAYNARD (1936). *The General Theory of Employment. Interest, and Money.* London: MacMillan.

LEIPERT, CHRISTIAN (1986). "Social Costs of Economic Growth". *Journal of Economic Issues* 20 (1): 109–31.

---------- (1987). *"Defensive Ausgaben in der Bundesrepublik Deutschland 1970 bis 1985: Absolute Werte und Relationszahlen mit dem BSP".* Berlin. Processed.

LUTZ, ERNST; MOHAN MUNASINGHE, and RAMESH CHANDER (1990). *"A Developing Country Perspective on Environmental Accounting".* Divisional Working Paper Nº 1990-12, Environment Department, World Bank.

MAGRATH, WILLIAM, and PETER L. ARENS (1989). *"The Costs of Soil Erosion on Java: A Natural Resource Accounting Approach".* Environment Department Working Paper Nº 18, August 1989.

PESKIN, HENRY; with ERNST LUTZ (1990). *"A Survey of Resource and Environmental Accounting in Industrialized Countries".* Environment Department Working Paper Nº 37, World Bank, August.

REPETTO, ROBERT; WILLIAM MAGRATH; MICHAEL WELLS; CHRISTINE BEER, and FABRIZIO ROSSINI (1989). *"Wasting Assets: Natural Resources in the National Accounts".* World Resources Institute, Washington, D.C.

SCHRAMM, GUNTER (1986). "Practical Approaches for Estimating Resource Depletion Costs". In Edward Miles, Robert Pealy, and Robert Stokes, eds., *Natural Resources Economics and Policy Applications: Essays in Honor of James A. Crutchfield.* Seattle and London: University of Washington Press.

UNITED NATIONS (1968). *"A System of National Accounts".* Publication E.69.XVII.3., New York.

UNITED NATIONS, ECONOMIC COMMISION FOR EUROPE (1987). *Environment Statistics in Europe and North America: An Experimental Compendium.* New York.

WARD, MICHAEL (1982). *Accounting for the Depletion of Natural Resources in the National Accounts of Developing Economics.* Development Centre Publication CD/R(82)3010. OECD, Paris.

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APPLYING ECONOMIC ANALYSIS TO ENVIRONMENTAL PROBLEMS: OPPORTUNITIES AND CONSTRAINTS*

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Abstract:

Economic analysis of environmental and natural resource management problems is receiving increasing attention. Whether the concern is with traditional pollution related issues, especially of air and water in urban areas, or with more complex natural resource management problems in rural areas, economists are increasingly being called upon to conduct analysis and offer policy advice for meeting these needs. This paper discusses the evolution of economic analysis of environmental concerns and considers some of the constraints to and opportunities for expanded economic analysis of environmental problems. Experience from both developing and developed countries is used to illustrate various points and an assessment of recent experience is offered.

Introduction

Economic analysis of environmental and natural resource management problems has become a "growth industry" of the 1990s. Increasing attention is being paid to how the concepts and techniques of economic analysis can be applied to natural resources management. This is true in both the developed and developing countries, and by national governments as well as bilateral and multilateral aid agencies and development banks.

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As economists, we benefit from this interest and the demand for our services. We are also, however, increasingly subject to the closer scrutiny that comes with this interest. Rather than hiding in the comfortable world of academic journals and professional meetings, applied resource and environmental economists are increasingly being asked to show how their theories and techniques can be used to address real, immediate problems, both at the project and at the policy level. This paper explores the historical evolution and present status of these issues from the perspective of one who has worked in this area for the past ten years and draws heavily on interactions with both developing countries and the major international development banks. The focus is largely on project-level analysis although macro policies may be equally or even more important in affecting levels of environmental quality. An historical overview is first presented to help in understanding the present state of economic analysis of environmental and resource management problems. This overview is then followed by a discussion of the present situation.

Changing Concerns, Changing Approaches

A century ago the industrial revolution and its induced changes promised dramatic gains in the incomes of people in many western countries. The factory and railroad were symbols of progress, and smokestacks emitting plumes of black smoke were seen as a positive sign of progress. This was still true as recently as 50 years ago when the world was beginning to recover from the worldwide economic depression of the 1930s. Natural resources were perceived as plentiful and governments and individuals were mainly concerned with the problems of rapid resource extraction and conversion, and finding markets for the products produced.

Although economic analysis had started with a heavy resource management focus in the time of Smith, Mills and Ricardo, by the 20th century it had begun to focus increasingly on questions of industrial development, capital formation, and government fiscal and monetary policies. Agricultural economics developed into a special field that was largely concerned with the productivity of crop-based agriculture or livestock systems. Natural resources and the environment were given scant attention by economists, other than as a source of inputs (resources) or as an essentially costless receptor for by-products and wastes (the environment).

In the field of economics the second quarter of the 20th Century was dominated by Keynes' publication of the *General Theory* in 1936 and the "Keynesian Revolution" that followed World War II. Nevertheless, a series of influential publications had appeared earlier that were to have later important implications for environmental economics. Pigou laid down principles of welfare economics in the first few decades of the century. In his major work, *The Economics of Welfare* (1920), Pigou expanded Marshall's concept of externalities into a broader economic theory of government intervention. He argued that externalities occurred when the actions of one economic agent unintentionally harm or benefit others, and as a consequence there is a divergence between private costs or benefits and the true social costs or benefits of the actions (Blaug 1986). These ideas have obviously had a tremendous impact on later thinking about the role of government, and the practice of social and environmental benefit-cost analysis of projects.

The question of the economics of natural resources received limited attention during this period. In the early part of the century the study of resources initially focussed on exhaustible resources; Gray (1914) used graphical analysis to examine diminishing marginal returns to exhaustible resources extraction. In what is now considered a classic article (although largely unnoticed at the time) Hotelling published "The Economics of

Exhaustible Resources" in 1931. Additional progress in this area would not really happen for another two to three decades until the U.S. President's Material Policy Commission (Paley Commission 1952) and Barnett and Morse of Resources for the Future (1963) focused attention on this issue.

During the depression of the 1930s, when major public works were undertaken for employment and economic stimulus, the U.S. government was beginning to examine the benefits and costs of large public works projects, many of which were water resource developments. The role of economics as a test of project desirability for public works began to gain acceptance. The 1936 Flood Control Act specified that new federal flood control projects be undertaken only if "the benefits to whomsoever they may accrue are in excess of the estimated costs" (Eckstein 1958).

Work on applied benefit-cost analysis of public investment projects continued after World War II and resulted in the 1950 publication by a U.S. government committee of a major report, "Proposed Practices for Economic Analysis of River Basin Projects", generally known as the Green Book. As described by Hufschmidt (1988), the Green Book was a very impressive document:

> "It was especially strong in stating the basic principles of welfare economics and microeconomics (although not in highly theoretical terms) and in applying those principles to develop realistic and workable standards and procedures for measuring benefits and costs for a number of project purposes--irrigation, flood control, navigation, electric power, watershed treatment, and, to a limited extent, recreation and fish and wildlife".

By the end of the 1950s, therefore, these three themes –welfare economics, the economics of exhaustible resources, and applied economic analysis of projects– were fairly well developed. The environment was not yet a major concern, but issues of natural resources management, both renewable and nonrenewable, were gaining prominence as reflected in the work of the Paley Commission (1952), Ciriacy-Wantrup (1952), Scott (1955) and Barnett and Morse (1963). At the same time the political independence of scores of nations in the years following the end of World War II was combined with a major international effort to promote economic development. Suddenly big investment projects were appearing everywhere, resources were being used at a rapidly growing rate, and problems of pollution and environmental degradation attracted increasing attention.

The following 30 years have witnessed a gradual change in focus and emphasis that reflect both growing public awareness of the issues of resource depletion and environmental degradation and the analytical approaches developed by economists and others to deal with these concerns.

Environmental concerns were a logical addition to existing theory and practice, particularly in the fields of welfare economics and project analysis. The goal was simple: develop approaches for improved analysis of projects that explicitly take into account environmental benefits and costs, as well as direct project inputs and outputs. Even if an activity is privately beneficial, it should not be undertaken unless there are also positive net social benefits when environmental benefits and costs are taken into account. The path to this goal is still somewhat elusive but considerable progress has been made. A brief review of the period since 1960 illustrates this evolution.

The 1960s: Pollution and Silent Spring

Sometimes a book is published that galvanizes public attention around a topic; Rachel Carson's *Silent Spring* (1962) helped set the environmental agenda for much of

the 1960s, and gave increased urgency to the work on applied environmental economic analysis which was then in its infancy. A major thrust in environmental economics during this time was how economic analysis can help to manage pollution, particularly water and air pollution.

Public and professional concerns focused on the pollution of air and water by industry, agriculture and domestic processes. At Resources for the Future in Washington, D.C., Allen Kneese carried out pioneering work on water and air pollution (1962, 1964). In Europe, the OECD led with the development of the "polluter pays" principle. This fairly straightforward concept stated that those who caused the pollution had a responsibility for either cleaning it up after the fact, paying compensation, or preventing the pollution from occurring. Since most of the "costs" of pollution were economic externalities, the use of Pigouvian taxes was advocated as one solution.

The focus on pollution and resource flows often seen as a "rich country" concern and not directly relevant to developing countries, many of whom implicitly took the view of "grow first, clean up later". Influenced by the Paley Commission (1952) findings, resource stocks were not a major focus although some groups, notably Resources for the Future, were concerned with these issues. John Krutilla's influential article "Conservation Reconsidered" appeared in 1967 and sparked renewed interest in a set of broader renewable resource issues.

The 1970s: Big Projects, Economic Growth and Limits to Growth

The environment gained high visibility in the 1970s with enactment of the U.S. National Environmental Policy Act in 1970 and sweeping air quality and water quality legislation. These events led to the Stockholm Conference on the Human Environment, 1972, which gave the official international organizational stamp to environment as a global concern. In 1972 the Club of Rome published its report, *The Limits to Growth* (Meadows *et al.*), and created worldwide concern over the issue of resource stocks and their longer term availability. Coupled with OPEC oil shocks, drastic changes in the international monetary systems, and recession and inflation, the world economy entered new, untested waters.

Environmental concerns also began to focus on the resource degradation impacts of large projects in both developed and developing countries. At the same time the World Bank set up an Environment Office.

Economic analysis of large projects was further refined and a number of important books appeared dealing with social-welfare based benefit-cost analysis, especially as related to developing countries: the UNIDO Guidelines (1972) and Little and Mirrless (1974). Mishan's book on the principles of benefit-cost analysis had appeared a few years earlier (1971) and Gittinger's book on agricultural project analysis appeared in 1972. None of these books gave major attention to environmental questions, per se, but they did lay out the framework for project analysis based on social welfare criteria incorporating distributional as well as efficiency effects rather than narrow private benefits and costs. This framework would later be very useful in carrying out broader "extended" benefit-cost analyses that include many environmental or natural resource effects of development projects.

The use of innovative valuation techniques was expanded, largely in the U.S. in the late 1970s and 1980s, and considerable experimentation was carried out using various contingent valuation methods (CVM) to determine the willingness-to-pay or willingness-to-accept-compensation for environmental change. The work of Bishop is notable on this

topic as well as his expansion of Ciriacy-Wantrup's work on Safe Minimum Stardards (1978). In addition, this period saw a rapid growth in the area of institutional economics and the questions revolving around property rights, entitlements and natural resource management, as exemplified by the work of Bromley (1978).

The 1980s: Stocks as Well as Flows; Resources Management

A growing maturity entered the discussion of economic policies and environmental/resource management policy in the 1980s. The richer, developed countries realized that there were limits to environmental management and to what any society could afford to do. Major progress was made in some places, particularly on air and water pollution. In Tokyo, for example, air quality improved considerably, but at a substantial economic cost.

If one term can characterize thinking during the 1980s it probably is "resources management". This term implies beneficial use of natural resources, but use that is tempered with concern for future generations. It is less environmental and more development oriented, but development that is sustainable and that protects the wide array of environmental services that we desire as societies.

In one sense the 1980s can be seen as a measured response to the alarmist limits to growth rhetoric of the 1970s. There are resource limits, but there are also important opportunities. The economics profession saw a merging of resource economics and environmental economics. Economists learned that they must work with other scientists to explore two aspects--resource use and resource conservation. This realization also resulted in greater attention being given to the two major types of policy issues--the individual project (both large and small), and the national level policies that affect the entire economy.

The dual micro-macro focus represents a growing awareness of the close links between the economic system, economic policies, and the level of resource utilization and management. Unfortunately the empty slogans of the past (e.g. growth with equity, integrated rural development) are being replaced with their modern day equivalent (sustainable development). This is not to say that these goals are not laudable; rather, they are exceedingly difficult to define and frequently result in contradictory policy advice (Dixon and Fallon 1989). What is encouraging, however, is the growing realization of the interconnected nature of countries, ecosystems, and government policies. To the extent this realization is reflected in government policies and the preparation and appraisal of projects, better development will result. A recent book edited by Schramm and Warford (1989) of the World Bank explores the relationships between environmental management and economic development from a number of perspectives.

The 1990s: Limited Growth?

As we begin the 1990s the world has entered another period of heightened environmental awareness, not unlike the 1970s. This time, however, the concerns are international and the agenda is global interactions and international resource management.

Spurred in part by the Bruntland Commission report, *Our Common Future* (WCED 1987), and a series of natural events (e.g. droughts) or man-made disasters (e.g. Chernobyl) international environmental issues have been picked up by the press, the politicians and the public. Global warming, sea level rise, toxic wastes, acid rain, Amazonian rainforests

and biodiversity all clamor for attention. There is growing realization that there are certain resource or ecological limits within "spaceship earth", and continued growth may not be sustainable or desirable. The rubric "sustainable development" itself has spawned a seemingly endless series of national, regional and international conferences and much debate about its meaning.

The Present Situation

Given this evolution of thinking about how to incorporate resource and environmental concerns into economic analysis, how successful are the attempts to accomplish this? The record to date is mixed. Economic analysis has been quite successful in addressing certain environmental problems or questions, especially at the project level, and less helpful in other cases. In part, this is a natural result of the inherent limitations of economics from a theoretical basis and the diversity of problems economics is being called upon to address. As a science, economics is an empirical, quantitative discipline that is ill suited to address certain subjective or qualitative topics. The "value" of human life is a well-known example of just one of these problem areas.

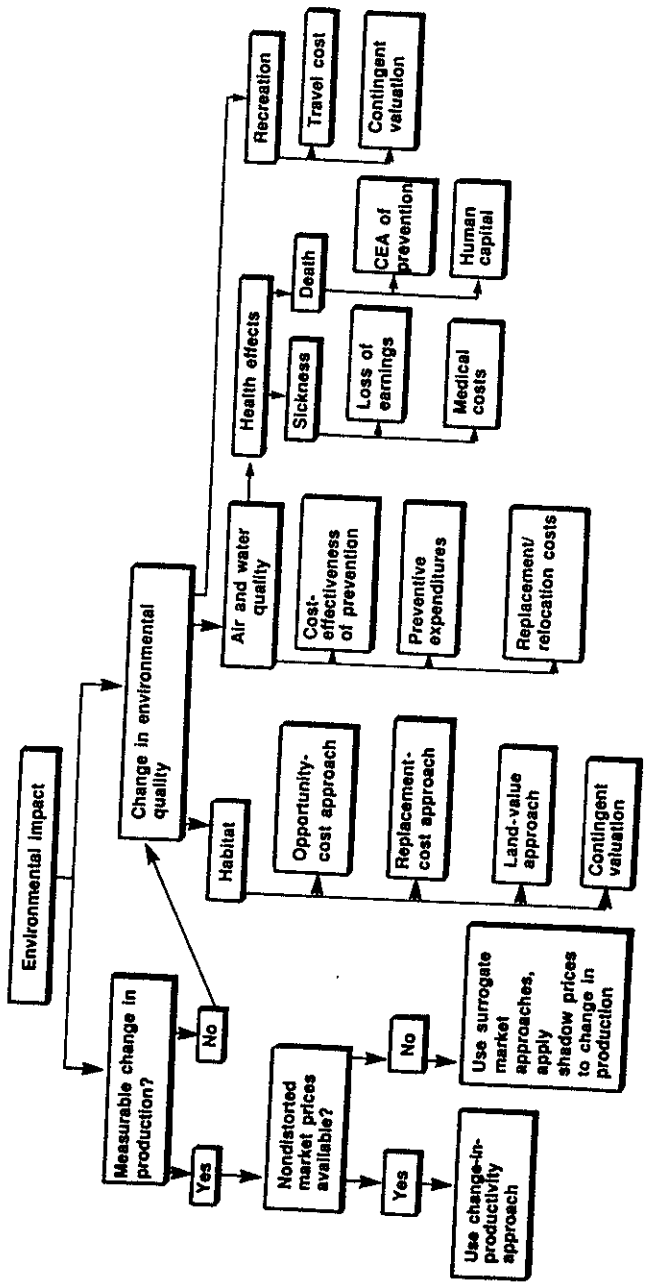
Other difficult areas abound in the environmental/natural resource management field: species preservation, genetic diversity, traditional social-cultural systems, and aesthetic concerns among others. Other topics that were once thought too subjective to value are now routinely analyzed within an economic framework. For example, the value of recreational resources is now commonly evaluated using the travel-cost approach, developed by Knetsch and others (Clawson and Knetsch, 1966). The use of survey based techniques to illicit information on willingness-to-pay or willingness-to-accept-compensation for various resources is increasingly accepted as a useful technique (even though the divergence between the two approaches has been a topic of some concern).

Still other environmental concerns result in changes in physical production or health that, if data are available, can be measured and valued. Some of these are the "easy ones" from an economic perspective--direct impacts on the production of goods and services that can be valued using market prices. These environmental benefits and costs can then be added to the other direct project benefits and costs to undertake what has been called an "extended" benefit-cost analysis resulting in a broader evaluation of alternatives. To reach this step, however, the potential environmental impacts have to be identified and measured (assessed), evaluated in monetary or qualitative terms, and incorporated into an evaluatory process (frequently some form of benefit-cost analysis). Details on valuation techniques are found in numerous references (see Pearce 1978; Sinden and Worrell 1979; Hufschmidt *et al.*, 1983; Dixon *et al.*, 1988).

Matching up economic technique with environmental effect is not an exact science. The actual technique used in any case will depend on a number of variables including time, data available, financial resources and the skill of the analyst. Figure 1 (Dixon and Bojo, 1988) presents one approach: a simple evaluation flow chart that starts with an identified environmental impact. Though by no means complete, this flow chart provides useful guidance on where to begin. A variant on this is seen in Table 1 from a recently completed manuscript on dams and the environment prepared for the World Bank (Dixon, Talbot, LeMoigne, 1989). It lists various potential environmental effects of dams, their economic impact, whether they are likely to be benefits or costs, and representative valuation techniques. Whereas Figure 1 presents generic impacts, Table 1 lists more specific environmental effects. Neither approach, however, tells which effects are the most important or of greatest concern. The integration of environmental and economic

FIGURE 1

A SIMPLE VALUATION FLOW CHART



Source: Dixon and Bojö (1988).

TABLE 1

SELECTED ENVIRONMENTAL EFFECTS OF MAJOR STORAGE DAM PROJECTS AND THEIR ECONOMIC IMPACTS

Environmental Effect	Economic Impact	Benefit (B) Cost (C)	Representative Valuation Technique
Environment on Dams			
1. Soil erosion - upstream, sedimentation in reservoir	reduce reservoir capacity; change in capacity; change in water quality; decrease in Power	B, C	change in production, preventive expenditures, replacement costs.
Dams on the Environment			
1. Chemical water quality - changes in reservoir and downstream	increased/reduced treatment cost reduced fish catch, loss of production	B, C	preventive expenditures, changes in production.
2. Reduction in silt load, downstream	loss of fertilizer, reduced siltation of canals, better water control	B, C	replacement costs, preventive expenditures avoided.
3. Water temperature changes (drop)	reduction of crop yields (esp. rice)	C	changes in production.
4. Health - water related diseases (humans and animals)	sickness, hospital care care, death; decrease meat and milk production	B, C	loss of earnings, health care costs.
5. Fishery - impacts on fish irrigation, spawning	both loss and increase in fish production	B, C	changes in production, preventive expenditures.
6. Recreation - in the reservoir or river	value of recreation opportunities gained or lost, tourism	B, C	travel cost approach, property value approach.
7. Wildlife and biodiversity	creation or loss or species, habitat and genetic resources	B, C	opportunity cost approach, tourism values lost, replacement costs.
8. Involuntary resettlement	cost of new infrastructure, social costs	B, C	replacement cost approach, "social costs", relocation costs
9. Discharge variations, excessive diurnal variation	disturbs flora and fauna, human use, drownings, recession agriculture	C	relocation costs, changes in production.
10. Flood attenuation	reduces after flood cultivation; reduces flood damage.	B, C	changes in production, flood damages avolded.

Source: Dixon, Talbot and LeMoigne (1989).

assessment is, therefore, necessary to ensure that the right questions are asked and the most appropriate alternatives are considered.

Limits of Current Practices

We face a situation where most major environmental problems are known and many appropriate economic analytic techniques have been developed. The broader technique of project analysis, especially benefit-cost analysis (B/CA) and cost-effectiveness analysis

are also well developed (UNIDO Guidelines 1972; Little and Mirrlees 1974; Gittinger 1982; Pearce 1978). And yet, the record of actual application is disappointing; this is true both for broader resource management issues and individual projects.

A fundamental division appears to exist between application of these approaches in developed and developing countries, in part due to differential access to financial resources and in part due to public and private awareness of environmental problems.

In *developed countries*, a major question is the appropriate level of environmental protection to adopt. Developed countries are relatively rich in data, trained manpower and financial resources. The differences between financial analysis and social-welfare (or economic) analysis are well known. Institutional arrangements and regulatory means exist to enforce decisions, once made. Tensions still exist, however. At the project level, enhanced environmental measures will usually mean increased financial costs in order to ensure larger social benefits. The decision-making process must contend with powerful forces on both sides. Well organized and financed project proponents must frequently contend with equally well organized (and sometimes powerful) "environmentalist" groups, be they private NGOs or government regulatory agencies. The net result of this tension has tended to be positive: projects today are more environmentally sound and development is more sustainable. Notable success in improving air and water quality, hazardous waste disposal, and land management have been achieved. These actions have usually required increased "up front" expenditures to ensure larger long-term benefits. In spite of progress, however, serious challenges such as acid rain remain.

In *developing countries*, however, home to a very large and rapidly growing share of the world's population, a different set of problems exist. In answer to the growing demands that environmental and resource concerns be accommodated while meeting economic development objectives, a number of responses are commonly encounteres. These include the following:

o *We already are doing it.* Many countries have elaborate environmental legislation on the books, but the problem is usually one of weak enforcement. In other cases, major projects are funded by bilaterals or multilaterals who also impose their own requirements. In this case, implementation of protection measures and post-completion maintenance are major problem areas.

o *We can't afford it.* One frequently hears the complaint that environmental protection measures are a "luxury" that developed countries can afford but that place an unacceptable burden on developing countries. In some cases, there is an element of truth in this assertion. More often, however, this view reflects a myopic approach to development whereby increased financial costs of environmental measures are given much more weight than the even larger social economic costs that result when no action is taken.

o *We can't measure it.* There is uncertainty about some cause and effect links, particularly where major natural ecosystems are involved. In many cases, however, the lessons learned from previously implemented projects or development programs very instructive in anticipating likely effects. Once the physical links are established, the economic connections can begin to be estimated. At the same time, as mentioned earlier, there are certain impacts or effects that are not appropriate for quantification and placing in monetary terms.

o *We don't know what we can do.* This is a real, but addressable, question. The growing worldwide interest in environmental assessment and applied economic analysis is one result of this question. The approach outlined in Figure 1 and the listing in Table 1 are but two examples of how to begin. More case studies are needed of actually applying

economic principles to real development problems in developing countries. Some examples, both ex-ante and ex-post, are given in two of our recent publications (Dixon and Hufschmidt, 1986; Hodgson and Dixon, 1988).

Selected Applications

The experience of actually applying economic analysis to environmental management problems in developing countries has been instructive. Based on selected examples from Africa and Asia, we see that economic analysis can add much to the overall analysis of alternatives, but that not all effects can be handled. Three cases, two from the Philippines and one from Nigeria, are briefly discussed to illustrate the process (fuller presentations are available in the cited references).

The first case involves the Tongonan Geothermal Power Plant in the Philippines. The environmental problem under consideration was the disposal of "wet" geothermal fluid from a power project located on the island of Leyte. The wastewater generated contained various heavy metals and other toxic substances and the question posed was how to best handle wastewater disposal. Seven disposal options were considered and a cost-effectiveness analysis was carried out to examine the direct and indirect costs of each option.

The options ranged from reinjection of geothermal wastewater on-site to disposal, with and without treatment, into two nearby rivers and two open-ocean outfalls. Details of the analysis are found in the case study prepared by Beta Balagot and Somluckrat Grandstaff and reported in Dixon and Hufschmidt (1986) and Dixon *et al.* (1988). The analysis considered the direct capital and operation, maintenance and replacement (OM and R) costs of each option as well as the likely environmental effects associated with each. Some of the latter effects were calculated in monetary terms (largely direct productivity costs on affected rice fields and fisheries). Other environmental effects were nonquantified and were included in a qualitative manner. The results of the analysis are presented in Table 2.

The interesting lesson from this study is that it was possible to place some of the environmental impacts into monetary terms. When these figures were combined with the direct project costs (financial costs) and the nonquantified costs, the results gave valuable guidance to decision makers. The wastewater disposal alternative finally chosen, reinjection, did not have the lowest direct costs (which were for untreated discharge into the Bao River, option 4) but did have a low total measurable cost and the lowest level of unquantified environmental costs. This finding would probably have been reinforced if time and data had permitted a fuller monetization of the nonquantified effects (the last column in Table 2).

A second case examined the situation of Bacuit Bay on the island of Palawan in the Philippines. A set of ecological and economic interactions result from the use of the bay and its watershed for three main industries: logging, fishing and tourism. In a classic case of economic externalities, the logging operations, legally carried out by a concession holder, result in soil erosion and sedimentation in the bay. Sedimentation in turn leads to coral death and turbid water, thereby, reducing fish catch and decreasing the attractiveness of the bay to a growing, high value diving resort business based largely on foreign sport divers.

The environmental and economic analysis of the situation (Hodgson and Dixon, 1988), consisted of an estimate of gross revenue generated under two options. Option 1 was a logging ban that preserved the fishing and tourism industry but resulted in financial

TABLE 2

COSTS OF WASTEWATER DISPOSAL OF THE TONGONAN GEOTHERMAL POWER PLANT, THE PHILLIPINES, UNDER ALTERNATIVE SCHEMES (MILLIONS OF PHILIPPINE PESOS)

Alternative	Direct Cost	Environment Cost	Total Measured Costs	Non-quantifiable or Non-Measured Costs
1. Reinjection	138.3	Unknown	138.3	Energy loss
2. Untreated Mahiao Discharge	120.2	Rice 7.3 Fishery 56.5	184.0	Freshwater fishery, stock health, laundry, bathing uses, human health, sea ecosystems
3. Treated Mahiao Discharge	359.3		359.3	Rice production and a lower loss on items in Alternative 2 with the exception of sea ecosystems
4. Untreated Bao Discharge	81.1	Fishery 56.5	137.6	Freshwater fishery, stock health, domestic use, human health, sea ecosystems
5. Treated Bao Discharge	359.1		359.1	Less than Alternative 4
6. Lao Point	243.1	Unknown	243.1	Non-quantifiable but high
7. Biasong Pint	353.2	Unknown	353.2	Non-quantifiable but high

Source: Dixon and Hufschmidt (eds) (1986).

costs to the loggers; Option 2, continued logging, resulted in short-term logging benefits but longer term financial and social costs from decreased fishery and tourism revenue. Since cost information was not available for each industry, we relied on data of gross benefits generated.

The results showed that the net "cost" of continued logging over a 10-year period with a 10% discount rate was about $ 17 million in terms of decreased tourism and fishery revenue. (Table 3). There are also important equity costs associated with continued logging since tourism and fishing generate more employment for local residents. Although a very simple analysis, the results have been used within the Philippines by the government to reassess its logging policy in this and other ecologically sensitive areas. The ultimate decision is a political one, especially since the logging lease is a legal arrangement. Nevertheless, this integrated environmental and economic analysis has highlighted important economic and social costs of resource management policies.

The third case is an analysis of the economics of afforestation in Nigeria (Anderson 1989). In this analysis, Anderson evaluated a variety of benefits produced by an afforestation project in a semi-arid region of Nigeria. These benefits included the production of wood and three products, arresting future declines in soil fertility, enhancing soil fertility over present levels, and the benefits of increased fodder availability.

Traditional economic analysis of afforestation projects focuses on wood and tree product production. In this region the returns to these products are generally low. Once

TABLE 3

GROSS REVENUES GENERATED BY INDUSTRIES IN BACUIT BAY, THE PHILLIPINES, UNDER OPTION 1 (THE LOGGING BAN) AND OPTION 2 (NO LOGGING BAN)

Tourism, fisheries, and logging industries: Ten-year sum of gross revenue, present value of gross revenue (x $ 1,000) using 10 and 15% discount rates

	Option 1	Option 2	Option 1 minus 2
Gross Revenue			
Tourism	47,415	8,178	39,237
Fisheries	28,070	12,844	15,226
(with tuna)	(46,070)[a]	(21,471)	(24,599)
Logging	0	12,885	-12,885
Total	75,485	33,907	41,578
Present Value (10%)			
Tourism	25,481	6,280	19,201
Fisheries	17,248	9,108	8,140
(with tuna)	(28,308)[a]	(15,125)	(13,183)
Logging	0	9,769	-9,769
Total	42,729	25,157	17,572
Present Value (15%)			
Tourism	19,511	5,591	13,920
Fisheries	14,088	7,895	6,193
(with tuna)	(23,122)[a]	(13,083)	(10,039)
Logging	0	8,639	-8,639
Total	33,599	22,125	11,474

[a]Tuna revenues (in parentheses) are not used to calculate the totals.

Source: Hodgson and Dixon (1988).

the other environmental and off-site benefits are added in, however, the benefits are found to be appreciable. This is a clear case of an activity that is socially beneficial but only marginally attractive from a private, narrow production focus. Appropriate policies are threrefore needed to encourage afforestation.

An Assessment of Recent Experience

Notwihstanding the growing number of cases where economic and environmental analysis have been successfully linked, it appears that there are definite limitations on what can be done, particularly in developing countries. This is due to several factors:

1. limitations on data or knowledge,
2. the existence of non-quantifiable impacts,
3. the major cumulative impacts of diffuse individual actions, and
4. major financial and/or political costs involved with some potential actions.

First, considerable uncertainty still exists about the cause and effect links associated with some ecosystems. For example, the exact effect of upper watershed deforestation on changed streamflow patterns downstream, particularly in larger watersheds, is not as clear as was previously thought. No doubt there is some impact but the full extent of flooding induced by land use changes is not certain (Hamilton with King, 1983). Similary, mangroves are important ecosystems that provide goods and services both within the mangrove and beyond. One important link is between the mangrove forest and the nearby fishery. It is known that a link exists via breeding habitat and nutrient flows but the exact magnitude is uncertain. The conversion of part of a mangrove forest to an alternative use may not effect the nearby fishery, while total conversion will. A gray area exists in between, however, and scientists do not yet know what portion must be maintained to ensure preservation of the associated fishery. Whitout this information, the economist cannot assess the fishery costs of mangrove conversion. A recent review of the ecology and economics of mangroves by Hamilton, Dixon and Miller (1989) illustrated the considerable data gaps that still exist when one considers the economic importance of this valuable resource.

Second, non-quantifiable (in monetary terms) impacts have already been mentioned. These range from changes in traditional lifestyles, to loss of historical or religious sites, to loss of as yet unused genetic material. While potentially very important, these impacts may not be amenable to coventional tools of economic analysis. They should, therefore, be retained in a qualitative manner in the analysis of alternatives. These concerns are very important in Latin America with its large areas of tropical rainforests and Amerindian populations.

Third, a much more fundamental problem is the fact that in most developing countries the major environmental problems are not the result of large, individual projects but are rather the result of actions by thousands or millions of individual decision makers--farmers, fishermen, small workshops or others actors. Because of the difficulty in controlling or regulating these groups, it becomes necessary to use economy-wide, macro policies to affect micro units. This realization is attracting increasing attention; the resulting focus on natural resources management via macro-level policies is reflected in recent writing by Repetto and Warford among others (see selected papers in Schramm and Warford, eds. 1989).

The diffuse nature of these micro units means that traditional environmental management tools--regulations, technology specification, fiscal measures--are much less effective than in the case of major development projects. Broader, economy-wide macro measures have the advantage of working through the economy and potentially affecting all resource users who are part of the economic system. This approach relies heavily on the market to send the appropriate signals. The weakness of this approach is the slow and uncertain nature of response to new policies. For example, it has proven much easier to control auto emissions by regulation of the small number of major car manufacturers than to control many other types of industrial pollution, particularly when a large number of small scale plants are involved.

Government policies designed to promote growth may prove counterproductive in some cases. Two recent studies on the interaction of Brazilian government policies designed to promote economic development and deforestation in the Amazon highlight some of these issues (Mahar 1989; Binswanger 1989). Binswanger, for example, analyzed the impact of tax policies and land allocation procedures on deforestation. Tax credits to promote ranching have also promoted deforestation with short-term private benefits and major long-term social costs.

Finally, major financial and/or political costs inherent in some actions may remove them from a realistic "feasible set". Economists, after all, do not make the final decisions. They can provide useful information to decision makers who must weigh it with many other factors, including political considerations. In other cases, certain environmental quality goals (such as for air or water) may be too expensive for an economy to afford, even using the most cost-effective technology.

Given these reasons for limited application of economic analysis to many natural resource for environmental management questions, should we be hopeful or pessimistic about the future? On balance, it appears that much has been gained and, in hindsight, we might be surprised at how far things have improved, especially at the project level. The care and attention rountinely given to environmental concerns today is a reflection of this evolutionary change.

In terms of economic analysis, two major thrusts are evident:

First, although considerable progress has been made with respect to valuing the benefits of environmental improvements, in many cases cost-effectiveness analysis is used to determine technological responses to predetermined emission standards for individual projects. This recognition of limits to the ability of individuals and societies to pay for environmental improvements is an appropriate balance to the understandable pressures to obtain improved levels of environmental quality, and the difficulty in measuring and valuing some of thoses benefits.

Second, the most useful approaches for valuing environmental effects, especially of projects, have frequently been the simplest. Change in productivity approaches, preventive expenditure techniques, opportunity cost approaches, travel cost techniques, and techniques based on human health effects have all proved helpful. The more experimental techniques, or those that require extensive data sets like the property-value approach, have had much more limited applications to date.

This is especially true in developing countries where the most useful approaches have been those that require the fewest assumptions and the least amount of data. Approaches that rely on physical goods and market prices (e.g. change in productivity, opportunity cost, relocation costs) have proved particularly useful. It has proved much harder to "sell" the results of more hypothetical or abstract techniques (e.g. the travel-cost approach).

To some extent, these trends in both developed and developing countries reinforce the "we are alredy doing it" perspective. The biggest hurdle in improving economic analysis of environmental management decisions has been the acceptance of the fact that environmental concerns are legitimate and that many can be handled at the project level by certain basic approaches. Improved environmental management is not dependent on the development of sophisticated, "magic-bullet" techniques.

The fact that major environmental problems still exist is less a comment on the state of development of analytical techniques than it is a reflection on the hard trade-offs that exist as individuals pursue their own self interests and one has to address the broader policy level. Precisely because of distortions in prices and other signals, uninternalized "externalities", and short time horizons, market failures occur that often lead to environmental problems. Policy failures are also a common cause of environmental degradation. The solution to these problems, therefore, requires more than merely doing a better job of assessing environmental impacts and valuing the associated benefits and costs, it also requires realistic political decisions that change policies and the "rules of the game". It requires political will. Improved economic analysis can aid in this process, but cannot cause it to happen by itself.

References

ANDERSON, D. (1989). "Economic Aspects of Afforestation and Soil Conservation Projects" in Schramm and Warford (eds.) 1989.

BARNETT, H. and C. MORSE (1963). *Scarcity and Growth: The Economics of Natural Resources Availability*. Baltimore: Johns Hopkins University Press.

BINSWANGER, H. (1989). "Brazilian Policies that Encourage Deforestation in the Amazon", Environment Department Working Paper Nº 16. Washington, D.C.: The World Bank.

BISHOP, R. (1978). "Endangered Species and Uncertainty: The Economics of a Safe Minimum Standard". *American Journal of Agricultural Economics* 60: 10-18.

BLAUG, M. (1986). *Great Economists before Keynes*. New York: Cambridge University Press.

BROMLEY, D. (1978). "Property rules, environmental rules and environmental economics". *Journal of Economic Issues* 12: pp. 43-60.

CARSON, R. (1962). *Silent Spring*. Boston: Houghton-Mifflin.

CIRIACY-WANTRUP, S.V. (1952). *Resource Conservation: Economics and Policies* (1st ed.). Berkeley: University of California Press.

CLAWSON, M. and J.L. KNETSCH (1966). *Economics of Outdoor Recreation*. Baltimore: Johns Hopkins Press.

DIXON, J.A. and L.A. FALLON (1989). "The Concept of Sustainability: Origins, Extensions, and Usefulness for Policy". *Society and Natural Resources* 2 (2).

DIXON, J.A. and M.M. HUFSCHMIDT, (eds.) (1986). *Economic Valuation Techniques for the Environment: A Casestudy Workbook*. Baltimore: Johns Hopkins University Press.

DIXON, J.A. with J.P. BOJO (1988). "Economic Analysis and the Environment", a report to the African Development Bank. Abidjan: AFDB.

DIXON, J.A.; R.A. CARPENTER; L.A. FALLON; P.B. SHERMAN; S. MANOPIMOKE (1988). *Economic Analysis of Environmental Impacts of Development Projects*. London: Earthscan Publications.

DIXON, J.A.; L.M. TALBOT; G. LEMOIGNE (1989). "Dams and the Environment: Considerations in World Bank Projects". Technical Report 110. Washington: World Bank.

ECKSTEIN, O. (1958). *Water-Resource Development: The Economics of Project Evaluation*. Cambridge, Mass: Harward University Press.

GITTINGER, J.P. (1972). *Economic Analysis of Agricultural Projects*. Baltimore: The Johns Hopkins University Press for the World Bank.

GRAY, L.C. (1914). "Rent under the assumption of exhaustibility". *Quarterly Journal of Economics* 28, pp. 446-489.

HAMILTON, L.S. with P.N. KING (1983). *Tropical Forested Watersheds: Hydrologic and Soils Response to Major Uses or Conversions*. Boulder: Westview Press.

HAMILTON, L.S.; J.A. DIXON, and G.O. MILLER (1989). "Mangrove Forests: An Undervalued Resource of the Land of the Sea" in *Ocean Yearbook 8*, edited by E.M. Borgese, N. Ginsburg, and J.R. Morgan. Chicago: University of Chicago.

HODGSON, G. and J.A. DIXON (1988). *Logging Versus Fisheries and Tourism in Palawan: An Environmental and Economic Analysis*. Occasional Paper Nº 7. Honolulu: East-West Center.

HOTELLING, H. (1931). "The economics of exhaustible resources". *Journal of Political Economy* 39, pp. 137-175.

HUFSCHMIDT, M.M.; D. JAMES; A. MEISTER; B. BOWER, and J. DIXON (1983). *Environment, Natural Systems and Development: An Economic Valuation Guide*. Baltimore: Johns Hopkins University Press.

HUFSCHMIDT, M.M. (1988). "Benefit-Cost Analysis: The Early Years 1933-1960". Mimeo. Honolulu: East-West Center.

KNEESE, A.V. (1962). *Water Pollution: Economic Aspects and Research Needs*. Washington, D.C.: Resources for the Future.

KNEESE, A.V. (1964). *The Economics of Regional Water Quality Management*. Baltimore: Johns Hopkins University Press.

KRUTILLA, J.V. (1967). "Conservation Reconsidered". *American Economic Review* 57, pp. 787-796.

LITTLE, I.M.D. and J.A. MIRRLEES (1974). *Project Appraisal and Planning for Developing Countries*. New York: Basic Books.

MAHAR, D.J. (1989). *Government Policies and Deforestation in Brazil's Amazon Region*. Washington, D.C.: The World Bank.

MEADOWS, D.; D.L. MEADOWS; J. RANDERS, and W.W. BEHRENS III (1972). *The Limits to Growth*. New York: Universe Books.

MISHAN, E.J. (1971). *Cost-Benefit Analysis.* New York: Praeger Publishers.
PALEY COMMISSION (President's Materials Policy Commission) (1952). *Resources for Freedom.* Washington, D.C.: U.S. Government Printing Office.
PEARCE, D.W. (ed.) (1978). *The Valuation of Social Cost.* London: Allen and Unwin.
PIGOU, A.C. (1920). *The Economics of Welfare* (1st ed.). London: MacMillan and Company, Ltd.
SCHRAMM, G. and J.J. WARFORD (eds.) (1989). *Environmental Management and Economic Development.* Baltimore: The Johns Hopkins University Press for the World Bank.
SCOTT, A. (1955). *Natural Resources: The Economics of Conservation.* Toronto: University of Toronto Press.
SINDEN, J.A. and A.C. WORRELL (1979). Unpriced Values: Decisions Without Market Prices. *New York: Wiley.*
United Nations Industrial Development Organization (UNIDO) (1972). Guidelines for Project Evaluation. New York: United Nations.
World Commission on Environment and Development (WCED) (1987). *Our Common Future.* Oxford: Oxford University Press.

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ENVIRONMENTAL RESOURCES, PUBLIC INPUTS AND FISCAL CONSTRAINTS

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Abstract:

We study the consequences of a binding constraint on the level of public expenditures directed at sustaining an environmental resource, which enters as a public input (alongside capital) into the economy-wide production function. As expected, the long run stock of that resource is reduced; however, we also find that the long run capital stock is reduced in a larger proportion. Also, the capital-environmental resource ratio becomes sensitive to changes in the rate of interest.

1. Introduction

Environmental resources are crucial regenerating assets of any economy[1]; they are normally involved in the most serious intertemporal misallocation problems in both industrialized and developing countries. One standard presentation is the so called problem of the control of pollution[2] where the output coming from a given production process raises the rate of depletion of a renewable resource, having a direct impact on the welfare (consumption) of economic agents. This effect competes against expenditures on "clean-up" activities that are usually financed by the public sector due to the common property nature of the resource in question. Thus, this paradigm-example emphasizes two crucial dimensions in the control of these resources: the level of production inducing a reduction of the stock *vis-à-vis* the (level or) rate of expenditures and other activities that help at regenerating resources. This allows some speculation on the relationship between growth and environmental resources; in particular, it is accepted that the latter are in danger of being misused in contexts characterized by fast growth and very low efforts directed at controlling resources. Perhaps a too direct extension of this reasoning to most Latin American countries could lead some to believe that we should not worry too much about environmental hazards given the stagnation and de-industrialization process that has taken place during the eighties: only a modest policing on the evolution