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USE OF COST BENEFIT ANALYSIS AND THE POLICY ANALYSIS MATRIX TO EXAMINE ENVIRONMENTAL AND NATURAL RESOURCE PROBLEMS

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ABSTRACT

Analysis of environmental and natural resource problems is often complicated by the simultaneous presence of both resource-related market failures and policy-induced distortions. In such a context, efforts to remove policy distortions may not be desirable if significant market failures remain, or conversely address the market failures may not be worthwhile if the economic environment remains highly-distorted. Despite the simultaneous presence of both types of problem, however,, most analysis has generally focused on one or the other exclusively. Cost-Benefit Analysis (CBA) and the Policy Analysis Matrix (PAM) are two tools that have been used in this way; their strengths and flexibility suggest, however, that they might be usefully combined into a single framework that allows a more integrated analysis of environmental and natural resource problems. This paper proposes an approach to doing so.

Use of Cost-Benefit Analysis and the Policy Analysis Matrix to Examine Environmental and Natural Resource Problems

Considerable concern has developed in recent years about the current rate and type of use of environmental and natural resources. Both market failures and policy distortions are thought to lead to considerable sub-optimalities in resource use[1]. Indeed, both sources of sub-optimality are likely to be present simultaneously in any given resource problem. In such a context, it is legitimate to ask whether efforts to remove policy distortions are desirable if significant market failures remain, or conversely whether it is worthwhile to address the market failures if the economic environment remains highly-distorted. Despite the simultaneous presence of both market failures and policy-induced distortions, most analysis has generally focused on one or the other problem exclusively. Cost-Benefit Analysis (CBA) and the Policy Analysis Matrix (PAM) are two tools that have been used in this way; their strengths and flexibility suggest, however, that they might be usefully combined into a single framework that allows a more integrated analysis of environmental and natural resource problems. This paper proposes an approach to doing so.

1. IMPACT OF MARKET FAILURE AND POLICY DISTORTIONS ON RESOURCE USE

The literature on the economics of environmental and natural resources has focused primarily on identifying market failures as a cause of sub-optimal use, and on devising remedies to these failures. For example, firms have no incentive to limit their use of rivers as a waste dump since such use comes at no cost to them. Possible remedies in such a case might include assigning property rights to the river or taxing firms according to the amount of damage they cause. Others have argued, however, that policy distortions are a primary culprit in many cases of sub-optimal resource use. Direct and indirect subsidies to logging, for example, encourage over-exploitation of forest resources. Removal of such policy-induced distortions, it is argued, would go a long way towards reducing the sub-optimality of resource use. In practice, it is likely that most resource problems will result from a mix of market failures and policy distortions.

The role of market failures and policy distortions in affecting the optimality of resource use can be illustrated with a simple example. Consider an exhaustible resource problem—to fix ideas, let us say farmers facing a fixed, non-renewable soil supply. Production of agricultural goods depletes the soil supply and also causes environmental damage. Optimal production choices in such a context would involve farmers choosing their input levels such as to maximize profits subject to the soil constraint, and taking into account the environmental damage:

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1. The word 'resources' will be used herein to refer to both environmental and natural resources, unless the context indicates otherwise. Resources are distinguished from other economic goods in being either non-producible (exhaustible resources) or subject to exogenously given production rules that economic agents can affect only indirectly (renewable resources). The distinction between environmental and natural resources is that the former are generally *consumption* goods (clean air, scenic sites) while the latter are generally *production* goods (fossil fuels, soil).

$$\text{Max} \quad \sum_{t=0}^{T-1} \rho^t \{ pf(a_t,s_t) - ca_t - eh(a_t) \} + \rho^T V(s_T) \qquad \text{st} \qquad s_{t+1} = s_t - g(a_t),\ s_0 = \sigma \tag{1}$$

where:
- a_t is use of input a at time t
- s_t is remaining soil stock at the beginning of time t
- $f(a_t,s_t)$ is the production function, which depends on input use and soil state
- $g(a_t)$ is the change in soil stock caused by use of input a
- $h(a_t)$ is environmental damage caused by use of input a
- $V(s_T)$ is the resale value of the land at the end of the planning period
- p is the price of the output
- c is the unit cost of input a
- e is the unit cost of environmental damage h(a)
- ρ is a discount factor, $\rho = (1+r)^{-1}$ where r is the discount rate

The current-value hamiltonian for this problem is

$$H(a_t,s_t,\lambda_t) = pf(a_t,s_t) - ca_t - eh(a_t) - \rho\lambda_{t+1}g(a_t) \tag{2}$$

The optimal control conditions for this problem, therefore, are:

$$H_a = pf_a - c - eh_a - \rho\lambda_{t+1}g_a = 0 \qquad t = 0, 1, \ldots, T-1 \tag{3}$$
$$-H_s = -pf_s = \rho\lambda_{t+1} - \lambda_t \qquad t = 1, 2, \ldots, T-1 \tag{4}$$
$$H_\lambda = -g(a_t) = s_{t+1} - s_t \qquad t = 0, 1, \ldots, T-1 \tag{5}$$
$$\lambda_T = V_s \tag{6}$$
$$s_0 = \sigma \tag{7}$$

The first condition determines the optimal level of input use and is of particular interest here. According to this condition,

$$pf_a = c + eh_a + \rho\lambda_{t+1}g_a \qquad t = 0, 1, \ldots, T-1 \tag{8}$$

The first term on the right-hand side is the marginal cost of the input. The second gives the value of the marginal environmental damage caused by input use. The third shows the long-term cost due to forgone future production resulting from marginal soil loss. The interpretation of this latter term can be seen most clearly by iterating (4) from t = T-1 backwards together with (6), to obtain

$$\lambda_t = \rho^{T-t} V_s + \sum_{i=0}^{T-t-1} \rho^i pf_s \tag{9}$$

That is, the multiplier λ_t shows the value of additional soil units to the final resale value of the land and to future production. This third term is generally referred to as a user cost or opportunity cost of current resource use.

These conditions imply that optimal use of the production input, a_t, requires that its marginal value product be equated to its cost *plus* the value of marginal environmental damage *plus* the long-term cost due to forgone production in the future resulting from the marginal soil loss. Now consider what would happen if the environmental damage h(a) did not accrue to the farmers themselves but rather to other economic agents (for example, through sedimentation of downstream reservoirs). In this case, farmers would not take the cost of such damage, eh(a), into account in making their production choices and the second term would drop out of (8). Production, therefore, would tend to increase, leading to higher resource use and more environmental damage than would occur under an optimal solution. This is a classic externality.

Consider next a case where land markets fail to reflect the productivity of the soil. In this case, $V_s=0$. The first term on the right-hand side of (9) would drop out, thus lowering the value of the multiplier λ. Since farmers would not benefit from maintaining their soil level to ensure high resale values, they would again tend to over-use the soil (they would not, however, ignore soil use entirely in this case, since there would still be a penalty to erosion arising from its effect on future production). This is a case of a market failure affecting user costs.

To these two sources of sub-optimality, both of which arise from market failures due to the specific nature of resources, is often added a third, due to policy distortions. To see this most clearly, let us return to the case where there are no failures in resource markets. Equation (8) indicates the conditions for optimal resource use of a private agent facing prices p, c, and e. In the absence of market failures or other distortions, these prices would reflect the value or cost to society of additional units of the output, the input, and the environmental damage. Suppose such prices are distorted, however. For example, suppose the price of the output is heavily subsidized, so that $p>p^*$, where p^* is the ideal, market-clearing price. In this case, the apparent marginal value of output will be higher, and farmers will produce more. Their rate of resource use and environmental damage remain optimal from a private perspective, but would be clearly sub-optimal from a social perspective.

2. EMPIRICAL ANALYSIS OF RESOURCE PROBLEMS

Although the problems to be addressed in resource issues are relatively well-understood qualitatively, empirical analysis has been severely constrained by formidable data requirements. In the problem outlined above, for example, determining optimal use rates for soil and other inputs would require knowledge of the production relationship, f(a,s), and of the way in which production affects the soil resource base, g(a), and the environment, h(a), all of which are complex bio-physical relationships. Valuing environmental damage is also fraught with difficulties, particularly where such damage takes the form of reductions in the amenity value of the environment or to the proper functioning of an ecological system. And where prices are distorted from their free-market levels by policy distortions, the real values of non-resource inputs and outputs are also uncertain, which as we have seen also affects resource use.

In this context, two tools provide some hope for detailed empirical analysis. The first is cost-benefit analysis (CBA), and the second is the Policy Analysis Matrix (PAM). CBA was originally developed as a tool to examine the economics of projects involving water resource development. Although its application to resource issues was thereafter neglected for some time, it has once again come into widespread use for this purpose [Krutilla and Fisher 1975, Hufschmidt et al. 1983]. The PAM combines elements of CBA and principles of trade theory to give a detailed picture of the nature and source of policy effects on specific activities [Monke and Pearson 1989].

2.1 Cost-Benefit Analysis

CBA relies on a comparison of the flow of costs and benefits between two alternative practices. The current activity is generally thought to be degrading, environmentally damaging, or otherwise represent a sub-optimal use of resources; the proposed alternative is generally thought to be more conserving, less damaging, or otherwise represent a pareto-improvement in resource use. Continuing with our soil conservation example, let us label these activities as degrading and conserving, respectively. The conserving activity might take the form of a proposed investment that would reduce or halt the rate of degradation (for example, an investment in terraces to reduce soil erosion), of an alternative, more conserving practice which completely replaces the current, degrading practice (for example, replacing field crops with agro-forestry practices), or of a standard to be achieved (for example, limits on soil runoff to reduce sedimentation damage downstream).

Leaving aside for the time being the inter-temporal nature of the problem, the structure of the analysis takes the following form:

	Revenues	Costs	Profitability
Degrading Activity	$A_d p_p$	$B_d c_p$	$(A_d p_p - B_d c_p)$
Conserving Activity	$A_c p_p$	$B_c c_p$	$(A_d p_p - B_c c_p)$
Net Benefits			$(A_d - A_c)p_p - (B_d - B_c)c_p$

Where A and B are the output and input coefficients, respectively, with subscripts d and c to indicate degrading and conserving activities, and where p and c are output and input prices, with subscripts p and s indicating private and social prices (this distinction is not necessary for this example, but will be used below). Each line is essentially a budget for an activity. In the top line, the current, degrading activity is examined; the value at top right indicates its profitability. Similarly, the second line examines the profitability of the alternative, conserving activity. The difference between the two activities is reflected solely in their input/output coefficients, A and B. The prices that would be faced in either case are assumed to remain constant. The third line then computes the net benefits of adopting the conserving activity to replace the degrading activity[2].

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2. Of course, both the degrading and the conserving 'activities' might consist of groups of activities rather than single activities. Likewise, the analysis could be carried out either at the level of single agents (at the farm level, in the soil conservation example above) or at a more aggregate level (for example, at a regional level). (continued...)

The interpretation of the net benefit is similar in each case: it represents the net benefit or cost that actors would encounter in switching from the current, degrading practice to the alternative, conserving practice. In general, this net benefit is only likely to be positive where the proposed conserving activity seeks to reduce the user cost of resource use. Where the conserving activity seeks to reduce damage caused by externalities, the benefits will by definition not accrue to the agents causing the damage (except to a very small degree). In this case, the net benefit will be negative and is interpreted as a cost of achieving the improvement in resource use or of complying with the standard to the agent undertaking the activity. These private costs of adopting the conserving activity are then compared to estimates of the social benefits that would be obtained from the resulting reduction in externalities. Since externalities are very difficult to quantify in practice, the costs of adopting the conserving activity are often compared to subjective judgements of the magnitude of the externalities to decide whether they are worth bearing[3].

The primary data requirement for CBA concerns the need to determine the input/output coefficients for each activity. While the coefficients required for the analysis of the degrading activity, A_d and B_d, are generally easily available from observations, those for the conserving activity, A_c and B_c, may often not be. Where the latter consists of, for example, a practice developed at an experiment station, the coefficients might be easy to determine, although even here actual field practice might differ in various ways from experiment station practice. Where the conserving activity consists of an imposed standard, the changes that are induced to the current activity need to be determined; the problems that are encountered in doing so differ depending on the way the standard is imposed, and have been examined in detail by Cory and Monke [1991].

There is no pretence of optimization in CBA. Options are considered pairwise, and there is no guarantee that other, unexamined, options would not be preferable to both. However, the method does allow comparison of numerous alternative practices. By comparing the net benefits to be obtained from two or more alternatives, the most profitable can be selected. Where the alternatives consist of different ways to implement a given standard, the least-cost way of achieving this standard (among the proposed methods) can be identified [Cory and Monke 1991]. Alternatively, the costs resulting from adoption of different standards of varying stringency might

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2.(...continued)

It is generally most illuminating to carry out the analysis at the most disaggregated level possible, since this will distinguish between costs and benefits accruing to different groups, a distinction which is crucial to implementation of the measures but which is often lost in aggregate analysis.

3. Note that if a decision is made that they are indeed worth bearing, difficult issues of implementation and income distribution will arise. Since these activities would impose net costs on private agents, they would not in general be adopted voluntarily. To achieve adoption might require either subsidies (in which case the net cost of switching to the conserving practice indicates the minimum required subsidy) or regulation (eg a standards approach). In the latter case, the private agents concerned will experience an income reduction equivalent to the net cost; where these agents are poor, such as in many developing country contexts, such distributive implications can be a cause of serious concern [Dasgupta and Mäler 1989].

be compared, to determine the most cost-effective level of abatement. As was well put by Cory and Monke, the method leads to efficiency without optimality.

2.2 Policy Analysis Matrix

CBA could be and has been extended to include the examination of the effect of divergences between private and social prices. Where the analysis of policy-induced distortions is of specific interest, however, the PAM provides a more specialized tool. Although it is also rooted in CBA, the PAM adds principles of trade policy to provide a convenient and illuminating way to categorize the various possible sources of distortion. The basic structure of a PAM analysis is as follows[4]:

	Revenues	Costs	Profitability
Private Prices	Ap_p	Bc_p	(Ap_p-Bc_p)
Social Prices	Ap_s	Bc_s	(Ap_s-Bc_s)
Divergences	(Ap_p-Ap_s)	(Bc_p-Bc_s)	$(Ap_p-Bc_p) - (Ap_s-Bc_s)$

Where all the letters and subscripts have the same meaning as in the previous example. The purpose of the PAM is to examine and compare the profitability of a given activity under observed, distorted prices and under social, 'efficiency' prices, and to identify the source of the distortions. Again each line is a budget for an activity—on the top line, profitability is calculated in private terms, as experienced by economic agents; on the second line, profitability is calculated in social terms. The differences shown in the bottom line indicate the extent and source of divergences between the two. Specifically, the bottom right value indicates whether the net effect of the policy distortions is to implicitly transfer resources to (if the value is positive) or from (if the value is negative) the activity. For example, an activity that is privately profitable but socially unprofitable would be implicitly subsidized. The left-hand entries on the bottom row indicate the source of the divergences; it is possible, for example, for one policy—say, trade policy—to penalize an activity while another policy—say, domestic factor policy—encourages it.

Note that in the PAM, the activity being analyzed remains unchanged while the prices at which the activity's profitability is determined change[5]. This is the reverse of the pattern seen previously in the CBA. The main tasks involved in constructing a PAM, therefore, involve constructing the original, private budget and then determining how to modify observed prices to account for the effect of various distortions. In principle, prices are modified to reflect the impact of market failures as well as of policy distortions; in practice, the approach is best suited to the analysis of the latter.

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4. A PAM would actually break down costs further into tradable and domestic factor components, a complication which is omitted here for ease of exposition.

5. This involves a restrictive implicit assumption on the nature of the technology, since in practice the level of input and output use would change if firms were confronted with the social price vector.

The PAM has not to date been used to examine resource problems. The only proposal of an approach to doing so, that of Cory and Monke [1991], is in fact essentially an application of CBA as defined here; they keep prices constant while changing the activity, and they do not make any use of the PAM's detailed disaggregation of policy effects. The primary obstacle hindering the PAM's application to resource problems is its specialized nature as a tool to examine policy effects.

3. COMBINING CBA AND PAM ANALYSIS

Given the strengths of CBA and PAM analysis in examining the market failure and policy distortion aspects of resource problems, respectively, combining them offers promise of achieving a more integrated and complete analysis of such problems. Fortunately, combining them is straightforward since both are at their core based on activity budgets.

Figure 1 shows a combined PAM and CBA matrix for the analysis of a resource problem, formulated here as a choice between a degrading and a conserving activity. The degrading activity is assumed to cause some external damage in addition to the direct costs and benefits which are quantified in the budgets; the conserving activity is assumed to cause less such damage. The CBA part of the analysis is read horizontally across the CBA/PAM matrix, the PAM analysis vertically. Essentially, the CBA/PAM matrix consists of two side-by-side PAMs, one for the degrading and one for the conserving activity, and two CBA calculations on the net benefits of adopting the conserving activity, one in private prices and one in social prices. This is illustrated in Figure 2.

Within each CBA and PAM section, traditional interpretations remain valid. By juxtaposing the PAM and the CBA analyses, however, additional information and insights can be acquired. Consider, for example, an externality situation in which the conserving activity seeks to reduce the external damage caused by the degrading activity, for example by imposing a standard that limits its extent. In this case, complying with the standard is likely to impose costs on the agents undertaking the activity, so that the net private benefit of switching to the conserving activity is negative. This cost of compliance could be compared to the estimated costs of the external damage to decide whether the costs are worth bearing. Since prices are distorted by policy interventions, however, the NPB does not indicate the real cost to society of reducing the external damage to the level set by the standard. By recalculating these costs in social terms, a much better estimate is obtained. The criterion, then, would be to impose the standard if the social costs of compliance (ie the NSB) are judged to be lower than the value of the reduction in external damage caused. The NPB would still indicate the cost of compliance borne by private actors, and hence provide an estimate of the income impact of imposing the standard and/or the minimum subsidy required to ensure voluntary adoption.

Comparing the private and social profitabilities of the two activities would indicate the degree to which policy distortions are responsible for the degrading activity being engaged in. The value calculated for *net transfers to conservation* (bottom right cell) indicates whether policy tends to encourage conservation over degradation or not. This value is calculated either as the difference between net transfers to the degrading and the conserving activities or as the difference between

Figure 1. Combined CBA/PAM For Analysis Of Resource Issues

	Degrading Activity			Conserving Activity			
	Revenues	Costs	Profits	Revenues	Costs	Profits	Net Benefits
Private Prices	$A_d p_p$	$B_d c_p$	$(A_d p_p - B_d c_p)$	$A_c p_p$	$B_c c_p$	$(A_c p_p - B_c c_p)$	$(A_d - A_c)p_p - (B_d - B_c)c_p$
Social Prices	$A_d p_s$	$B_d c_s$	$(A_d p_s - B_d c_s)$	$A_c p_s$	$B_c c_s$	$(A_c p_s - B_c c_s)$	$(A_d - A_c)p_s - (B_d - B_c)c_s$
Divergence	$A_d(p_p - p_s)$	$B_d(c_p - c_s)$	$A_d(p_p - p_s) - B_d(c_p - c_s)$	$A_c(p_p - p_s)$	$B_c(c_p - c_s)$	$A_c(p_p - p_s) - B_c(c_p - c_s)$	$(A_d - A_c)(p_p - p_s) - (B_d - B_c)(c_p - c_s)$

Notes: A_i output coefficient for activity i, i=d (degrading) or c (conserving)
B_i input coefficient for activity i, i=d (degrading) or c (conserving)
p_j output price, j=p (private) or s (social)
c_j input costs, j=p (private) or s (social)

Figure 2. Schematic View of Combined CBA/PAM

	Degrading Activity			Conserving Activity			
	Revenues	Costs	Profits	Revenues	Costs	Profits	Net Benefits
Private Prices	A_d	B_d+C_d	D_d	A_c	B_c+C_c	D_c	Net Private Benefits (NPB)
Social Prices	E_d	F_d+G_d	H_d	E_c	F_c+G_c	H_c	Net Social Benefits (NSB)
Divergences	I_d Output Transfers	J_d+K_d Input Transfers	L_d Net Transfers	I_c Output Transfers	J_c+K_c Input Transfers	L_c Net Transfers	Net Transfers to Conservation

Letters in PAM Matrices correspond to standard PAM cell names:

Private Profits $D_i=A_i-(B_i+C_i)$ Output Transfers $I_i=A_i-E_i$ Net Private Benefit $NPB=D_d-D_c$

Social Profits $H_i=E_i-(F_i+G_i)$ Input Transfers $(J_i+L_i)=(B_i+C_i)-(F_i+G_i)$ Net Social Benefit $NSB=H_d-H_c$

Net Transfers $L_i=D_i-H_i=I_i-(J_i+K_i)$ Net Transfers to Conservation $= NPB-NSB = L_d-L_c$

the net private and social benefits to switching to the conservation activity, both of which give the identical result, as can be verified from Figure 1. If this value is positive, it indicates that the net effect of policy distortions is to favor the conserving activity compared to the degrading activity. Note that this does not imply that it is favored in an absolute sense—indeed, both activities might be highly taxed, in which case a positive net transfer to conservation implies the conserving activity is less taxed[6]. Distortions would be particularly pernicious if they made a socially unprofitable degrading activity appear to be privately profitable and/or a socially profitable conserving activity appear to be privately unprofitable. If such cases are encountered, they would represent 'win-win' cases in which removing distortions would also reduce the mis-use of resources[7].

It is not uncommon to find that policies counteract each other to some degree. As in all PAM analysis, the source or sources of the divergence can be identified from the disaggregation of

6. Note that the result that government policy discourages conservation (say) is only valid for the specific pair of activities being compared. Other conserving activities might be encouraged by distortions. Only if a net transfer away from conservation is found in comparing numerous such pairs can a more general conclusion that policy tends to discourage conservation in general be reached.

7. Note, however, that economic actors would not necessarily switch to the conserving activity if the distortions were removed and the degrading activity become unproftiable, since the specific conserving activity being examined is only one of many possible alternative activities. In particular, they might switch to another degrading activity if that is their next most profitable alternative at the new prices.

revenue and cost categories. Here too, the difference between, say, distortions on tradable costs across the two activities indicate the degree to which trade policy preferentially affects one or the other activity (these differences are not shown in figures 1 and 2). Since policies serve many non-efficiency objectives in addition to efficiency objectives, it may not in practice be realistic to expect that all policy distortions could be removed, even to correct very pernicious cases. The detailed disaggregation of policy effects provided by the PAM would be particularly useful in such instances by allowing the most important sources of the divergence to be identified. Alternately, the analysis could be conducted using social prices that would result if only a specific sub-set of policy distortions were removed.

The discussion so far has not touched on the inter-temporal nature of many resource problems. For ease of exposition, both the CBA and the PAM matrices have been shown as if they were single-period constructs. Before examining how a combined CBA/PAM could be implemented to address an explicitly inter-temporal problem, however, it is worth noting that there are cases where a single-period framework is appropriate. The most obvious such case would arise if both the degrading and the conserving activity remain constant over time and the external damage caused by the degrading activity (which would be wholly or partially abated by the conserving activity) has no inter-temporal links. The purest example would be noise, which inflicts an external cost only while it is actually being generated. The external damage drops to zero as soon as the activity ceases, and does not accumulate. In this case, the costs and returns to each activity would not vary from period to period and the problem can be handled in a single-period framework, with any initial costs of switching to the conserving activities are depreciated over a suitable time period.

As soon as any kind of inter-temporal linkage is introduced, however, a single-period CBA/PAM becomes inappropriate. Such linkages might arise either because the external damage caused by the degrading activity is cumulative, or because the activities change over time. Soil conservation problems, for example, clearly require an inter-temporal approach because yields and costs are unlikely to remain constant under either the degrading or the conserving activity and the external damage—typically, sedimentation of reservoirs—is cumulative.

Two approaches are possible to introducing a time element into a CBA/PAM matrix. The simplest is to treat the value of each cell as the net present value of the values in each period over the period of analysis. Thus in the cell for private revenues under the degrading activity, previously shown as $A_d c_p$, we would have $\sum^T_{t=0} \rho^t A_{dt} c_{pt}$, where the subscripts t indicate the time period, with T the last period of the analysis. Likewise, private costs under the degrading activity, previously shown as $B_d p_p$, would become $\sum^T_{t=0} \rho^t B_{dt} p_{pt}$, and so on.

The second approach involves linking a sequence of CBA/PAM matrices, one for each time period. Time would thus become a third dimension to the two already present in the matrix. A summary matrix providing the net present values for each cell could also be prepared, of course, and would give identical results to that prepared under the first method. This second method would, however, provide an explicit time path for each of the variables. Collapsing all time periods into a single net present value would obscure such paths. As the values of the technical coefficients change over time, both the net benefits of conservation and the relative impact of policy distortions

will vary. Some policy distortions, for example, might have a small total effect over the entire period of analysis but be critical at certain periods. Likewise, a positive net present value for the net benefits of conservation might hide long periods in which this value is negative.

4. CONCLUSIONS

The interaction between market failures and policy distortions causes significant problems, both conceptual and empirical, in the analysis of resource problems. The combination of CBA and PAM analysis proposed here has considerable potential in helping examine these problems.

5. REFERENCES

CORY, Dennis, and Eric MONKE, 1991. "Using the Policy Analysis Matrix to Address Environmental and Natural Resources Issues." (mimeo)

DASGUPTA, Partha S., and Karl-Göran MÄLER, 1989. "Social Cost Benefit Analysis and Soil Erosion." In F. Archibugi and P. Nijkamp, eds, *Economy and Ecology: Towards Sustainable Development*. Dordrecht: Kluwer Academic Publishers.

HUFSCHMIDT, Maynard M., David E. JAMES, Anton D. MEISTER, Blair T. BOWER, and John A. DIXON, 1983. *Environment, Natural Systems, and Development: An Economic Valuation Guide*. Baltimore: The Johns Hopkins University Press.

KRUTILLA, John V., and Anthony C. FISHER, 1975. *The Economics of Natural Environments: Studies in the Valuation of Commodity and Amenity Resources*. Baltimore: The Johns Hopkins University Press for Resources for the Future.

MONKE, Eric A., and Scott R. PEARSON, 1989. *The Policy Analysis Matrix For Agricultural Development*. Ithaca: Cornell University Press.