Benefit-cost analysis with and without environmental preservation: a modified approach*

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Summary: 1. Introduction; 2. Fixed supply and expanding demand for natural areas; 3. The modified approach: introducing the foregone environmental preservation benefits as a cost; 4. The model under uncertainty; 5. The configuration of acceptable projects considering environmental preservation benefiets; 6. The nature of the basic parameters and their estimation.

The purpose of this paper is to show what are the necessary modifications in the cost-benefit analysis framework, as compared to the conventional approach, with a view to evaluate development projects which result in the loss of important environmental preservation benefits.
Towards that end, the following aspects are introduced in the new approach: (a) the inclusion as a cost of the lost environmental preservation benefits induced by a project in its benefit-cost stream; (b) the fact that environmental preservation benefits appreciate relative to development benefits due to a positive rate of technological decay and due to expanding demand and fixed supply of natural areas.
In this modified context, the minimum development benefits required from a stereotyped project to be socially profitable are estimated in different circumstances: with and without an appreciation rate for environmental preservation benefits, and with and without a depreciation rate for development benefits. Finally, guidelines are given on how to estimate the basic parameters of the modified cost-benefit approach so that it can be operational in project appraisal.

O objetivo deste artigo é mostrar de que forma a análise de custo-benefício tradicional deve ser modificada para tornar-se um instrumento útil à avaliação social de projetos que acarretam importantes custos ambientais irreversíveis.
Com este fim, os seguintes aspectos são introduzidos na análise modificada: a) a inclusão do custo ambiental induzido por um projeto no seu fluxo de custos e de benefícios; b) o fato de que os benefícios ambientais aumentam em relação aos benefícios do desenvolvimento devido à taxa positiva de decaimento tecnológico e à crescente demanda pelos serviços produzidos por áreas naturais, cuja oferta é inelástica.
Nesse contexto modificado, estimam-se os benefícios mínimos de um projeto padrão, de forma a garantir sua rentabilidade social em diferentes circunstâncias: com ou sem taxa de valorização dos benefícios ambientais da preservação e com ou sem taxa de depreciação dos benefícios do desenvolvimento. Finalmente, sugerem-se maneiras de estabelecer parâmetros básicos para a análise modificada de custo-benefício, a fim de que ela seja útil na avaliação de projetos.

1. Introduction

There has been considerable debate among economists on alternative ways to incorporate the environmental effects of projects in the conventional cost-benefit decision framework. As it is well known, the profitability of a project is determined by four factors: (a) the stream of benefits it generate; (b) its stream of costs; (c) the time period over which they

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occur; (d) the discount rate applied to benefits and costs so that they are put into a common unit of measurement in terms of time. Two main approaches have been suggested in connection with the objective of protecting the environment in cost-benefit analysis.

First, it has been advocated lowering discount rates so that future environmental benefits/costs and future generations are not discriminated against, since the weighting process gives lower weight to them the higher is the discount rate (see Markandya & Pearce, 1988). However, this procedure is defective insofar as the relationship between discount rates and the environment is not so simple. Two contradictory effects arise in this connection. On the one hand, it is true that lower discount rates could imply less direct natural resource use because the rate of exploration of natural resources would decrease (see any text-book for this result). On the other hand, lower discount rates imply more investment, which in turn requires more natural resources to be exploited and probably a higher level of pollution (see Markandya & Pearce, 1988).

The other approach consists in identifying and adjusting the relevant stream of benefits and costs, in particular the environmental costs induced by a project, and applying the usual cost benefit investment rules, which seems a less arbitrary way of incorporating environmental concerns in the decision framework. In this context, the purpose of this paper is to provide a modified cost-benefit approach able to socially evaluate projects destructive of important environmental preservation benefits.[1] Krutilla and Fisher (1975) have been pioneers in modelling how cost benefit rules would have to be changed to incorporate irreversibly lost environmental preservation benefits induced by projects. Porter (1982), following the work of Krutilla and Fisher (1975), extended and formalized the same model in a convenient way. This model is used as a benchmark here.

The structure of this paper is as follows. A brief outline is given in section 2 on the basic facts that are to be incorporated into the model of the section following it and which are expressed by declining net development benefits and appreciating environmental preservation benefits over time. Section 3 develops the basic model that shows the main modifications necessary to cost-benefit techniques. In section 4, it is shown how the introduction of uncertainty would affect the results of the model. In section 5, estimates are derived for the minimum development benefits required from a stereotyped project so that its social profitability is ensured in the presence of lost environmental preservation benefits. This is done considering different rates of growth for environmental preservation benefits as well as different posibilities for development benefits. Section 6 lays some guidelines to estimate the basic parameters of the model so that it can be useful for project planning and appraisal.

2. Fixed supply and expanding demand for natural areas

Pigou (1952) was the first economist who emphasized the need of governmental intervention to defend the exhaustible natural resources of a country from spoliation for the present and future generations (see Krutilla, 1967). Certainly, Pigou has started the econom-

[1] These represent all the components that affect human welfare with respect to the preservation of natural areas: the direct uses values, as for instance the medicinal value of plants, preferences towards the mere existence of natural areas, the value of ecological functions performed by them, regardless of the existence of markets as well as what is called option value, to be explained later on. This is called the total economic value of an environmental resource. See, for instance, Johansson (1990). See also section 6.

ics of conservation thinking. Until quite recently, this literature has focused on the question of the optimal intertemporal utilization of the fixed natural resources stocks.[2] Originating with Malthus's worries, there seemed to be a consensus that the resource base ultimately would be depleted.

However, the empirical studies on testing the thesis of natural resource scarcity have not been conclusive to support the idea that the resource base would be ultimately depleted, which would impose a strong limit to growth. For instance, early studies showed that there had been a relative downward trend it most of the natural resources commodities' prices compared to commodities and services in general (see Potter & Christy, 1962; Barnett & Morse, 1963). At that time, these results were explained by the fact that technological progress had compensated quite adequately for the depletion of the higher quality natural resource stocks and this would imply that the industrial economy would be decreasing its degree of dependence from the natural resource sector over time and, ultimately, the raw material inputs to industrial production could be only mass and energy. However, more recent studies show that although prices have been fairly stable or have been even falling for some resources over the decades preceding 1970, rising real prices for a number of key mineral resources and energy resources over the 1970s and the 1980s lead us not to be conclusive on the thesis of natural resource scarcity (see Fisher, 1981).

Already in the 1960s, another source of concern was related to the quality of the environment. Although the main objective of their study was to test the natural resource scarcity thesis, Barnett and Morse (1963) concluded that the quality of the physical environment was deteriorating: the landscape, water, and atmospheric quality were worsening. This recognition has been associated with a progressive change it the main concern of the economics of conservation, or, as this last more recently has been called, environmental economics. This change has meant the introduction of qualitative elements into the analysis. The literature has progressively shifted its focus from the management of natural resource stocks for the use of future generations to the concern of providing for the present and future the amenities associated with unspoiled natural environments. The recognition that the market fails to make adequate provision of the natural areas associated amenities has been fundamental in shaping this broadened literature. The reasons why there is the need of public intervention to secure an adequate level of supply of natural environments are several.[3]

The first is that there are many problems related to the natural environment which involves the irreproducibility of unique phenomena of nature and/or the irreversibility of some consequences bad to human welfare. Consider an area with some unique natural attributes as, for instance, the Grand Canyon in the US, or the Amazon Forest in Brazil. The area can be used for certain recreation and/or scientific research activities which would be compatible with the preservation of the natural environment, or for extractive activities such as logging or hydraulic mining, which would have adverse environmental consequences, some of which likely to be irreversible. A private resource owner would consider the present value of the net income stream from the alternative uses and follow the course of action which would lead to the highest present value. If this last use is incompatible with preserving the environment in its natural state, it is unlikely that the market will allocate the resources efficiently. Private and social returns are likely to diverge significantly.

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[2] In a parallel line, already in the 50s, renewable resources models were developed to show the optimal sustained rate of harvest for these resources. See Fisher (1981).

[3] Most of the arguments exposed in this section have been developed by Ciriacy-Wantrup (1952).

Secondly, it seems that the utility to individuals of direct association with natural environments may be increasing while the supply is not easily expanded by technology. In particular, the idea of option demand is highly relevant: this demand is generated by a willingness to pay for keeping an option to use a natural area that would be difficult or impossible to replace and for which no close substitute is available. The existence of this option demand may be independent of the intention to use the natural area in question: indeed, the option may never be exercised. It is unlikely that a private resource owner can appropriate this value, given the nature of the value in question and the difficult of marketing that option.[4]

Another very important issue related to the preservation of natural areas is the lack of complete knowledge on the potential applications of the biodiversity stock of ecosystems in different fields like medicine, agriculture, industry etc. The economic value of this stock is likely to be very large, although much is yet to be learnt before a definitive figure for this value is given. For instance, the economic value of botanical specimens for medicinal purposes has already been recognized as very important. Approximately half of the new drugs currently being developed are obtained from botanical specimens. Cortisone, digitalis, and heparin are examples of drugs which are derived from natural vegetation or zoological sources. As there is incomplete information on the full potentiality of uses derived from the biodiversity stock contained in natural environments, it becomes very relevant to keep open the option to examine all species in the future.[5]

The third important aspect to consider is that the real cost of slowing down the conversion of rare natural environments for development purposes may not be very large, considering the technological change and increasing preferences for natural areas. With the continued advance in technology, more substitutes for conventional natural resources will be found for the industrial and agricultural sectors and thus decreasing the degree of dependence of production on conventional sources of raw materials. On the other hand, technological progress has had clear effects on the production of goods and services but not on the production of natural phenomena. In fact, it is unlikely that technology will advance to the point at which certain natural features of natural areas could be replicated, or, in other words, the loss of environmental atributes is likely to be irreversible. The implication of the asymmetric effects of technological change its that while the supply of goods and services can be expanded from a given resource base, the supply of natural phenomena is virtually inelastic or decreasing in the process of development.

The implication of irreversibility and asymmetric technological change for the social valuation of natural areas *vis-à-vis* produced goods is that it is very likely that environmental amenities will be appreciating in value relative to produced goods over time. This can be seen in figure 1 through a transformation function (*PP*), which shows the production possibilities of a economy with the usual concavity properties, having along its vertical axis amenities derived directly from association with the natural environment (*E*) and along its horizontal axis produced goods (*C*). The curves *CIC*1 and *CIC*2 stand for the community indifference curves, considering tastes as constant.

The effect of the asymmetric technological change is to stretch along the horizontal axis the transformation function, which was originally represented by *PP*1 and now is represented by *PP*2 as advances in technology happen to occur, as Krutilla (1967) has emphasized.

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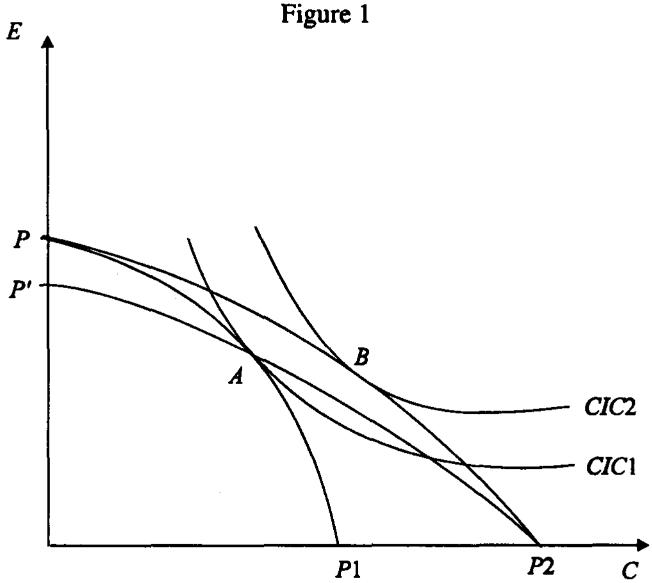
[4] On the notion of option demand, see Weisbrod (1964), Arrow & Fisher (1974), Henry (1974a, 1974b).

[5] On the use of plants for medicinal purposes, see Kreig (1964).

The curve $P'P2$ is still flatter reflecting the irreversible conversion of part of natural areas for development purposes. Considering tastes as constant, if we take the effect of technological progress over time, the marginal trade-off between manufactured goods and natural amenities will progressively favour the latter, which in the diagram is shown from the passage of the equilibrium point *A* to *B*. From *A* to *B*, the relative price ratio *Pc/Pe* is lower. Natural environments will have appreciating value whith the passage of time as technology is improved. This same result would be obtained if we consider technology as constant but a change in tastes favouring amenities derived from natural areas (*E*). In this case, the relative price ratio *Pc/Pe* would be still lower, as the community indifference curves would be flatter reflecting the higher relative value of *E* compared to *C*.

Figure 1



The above facts have important dynamic implications. At any point of time characterized by a level of technology which is less advanced than at some future date (represented by *PP*1), the conversion of the natural environment into development to produce a given level of goods has proceeded further than it would have with the more advanced technology (represented by *PP*2).[6] Or in other words, to produce a given level of goods today will be compatible with a certain level of environmental preservation, which is lower than it would have been the case if the same goods were to be produced tomorrow with a more advanced technology. Moreover, considering technology as constant and shifting preferences in favour of enjoying the amenities from the environment, the conversion of natural areas to development would also have proceeded further than it would have if the future composition of tastes had prevailed. Given the reasons for believing in the irreversibility of converted natural environments, it will be the case that the conversion of natural areas to development purposes will be higher than it is optimal from the social point of view. This justifies incorporating lost environmental preservation benefits of increasing value as a cost in any decision to develop a natural area.

[6] See Krutilla & Fisher (1975) for the modelling of this situation using optimal control theory.

3. The modified approach: introducing the foregone environmental preservation benefits as a cost

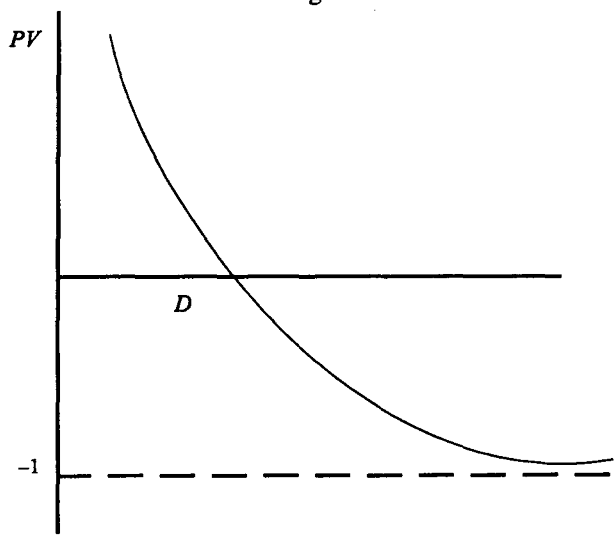
The traditional practice in the evaluation of a proposed development project in a natural area has been to ignore the preservation alternative. The traditional manuals on project appraisal and planning do recognize the existence of the negative environmental externalities induced by projects, although they do not prescribe how to treat them in an operational way. The model to be presented in this section intends to overcome this shortcoming (see Porter, 1982, for a complete derivation).

In fact, the relevant question was simply whether the flow of benefits derived from development exceeded the flow of costs, both in present value terms. For instance, the present value (*PV*) of a project that initially costs $1 and generates instantaneous benefits of $*D* (*D* for Development) forever after would be calculated as given by equation (1) considering a social rate of discount *i*:

$$PV = -1 + \int_{t=0}^{\infty} De^{-it}dt = -1 + \frac{D}{i} \qquad (1)$$

The relationship between *PV* and *i* is shown in figure 2. In the limiting case, where the flow of benefits is just equal to the flow of costs, from (1) it is the case that $D = i$. Projects that are acceptable are those for which $D > i$, corresponding to a positive *PV*.

Figure 2



Given the reasons presented in section 2, the modifications to the benefit costs analysis include two new elements: (a) the inclusion as a cost of development of the foregone environmental preservation benefits from the undisturbed area; (b) the introduction into the analysis of the belief that development benefits decline relative to preservation benefits.

The development of a natural area precludes any benefits society might have derived from the continued existence of the natural area in its original state. This means that in the present value calculation of any decision to convert a natural area for development purposes

it must be included as a cost of the project the foregone flow of net benefits from preserving the area. The nature of these benefits encompasses any use and nonuse values which affect human welfare with respect to the existence of environmental resources and in section 6 they will be made more precise where estimation problems are dealt with. Let us suppose that these environmental preservation benefits are $\$E$ (and E for environmental preservation benefits). In this case, the calculation of the project's PV becomes:

$$PV = -1 + D / i - \int_{t=0}^{\infty} Ee^{-it} dt$$

or

$$PV = -1 + D / i - E / i \tag{2}$$

Although the relationship between the PV and i remains as shouwn in figure 2, the acceptance rule for projects has been made more stringent, that is, $D > i + E$ if the PV is to be positive. The interpretation of the modified approach at this stage is quite obvious: the development benefits generated by a project have to be larger if the project is to be considered acceptable from the social point of view.

The second aspect of the modified approach is related to the time paths of development and preservation benefits. Accordingly, development is seen as the extraction or production of a physical product which technological change will probably make less valuable with the passage of time. In contrast to development, some factors already mentioned in the last section tend to make environmental preservation more valuable over time: increasing demand due to rising incomes, shifting preferences in favour of environmental "consumption", and a inelastic supply curve due to the difficulty of reproducing natural phenomena. If we assume a constant rate of growth for environmental preservation benefits ($\$E$) and also a constant rate of decay for development benefits ($\$D$), as well as that both are continuous variables, the time paths of environmental preservation benefits ($\$E$) and development benefits ($\$D$) are described by equations (3) and (4)

$$E_t = E_0 e^{\beta t} \tag{3}$$

$$D_t = D_0 e^{-\partial t} \tag{4}$$

where E_0 and D_0 are the initial values of environmental preservation and development benefits, E_t and D_t the environmental preservation and development benefits at time t, respectively, $\beta > 0$ and $\partial > 0$.

In this case, the PV is given by:

$$PV = -1 + \int_{t=0}^{\infty} D_0 e^{-(i+\partial)t} dt - \int_{t=0}^{\infty} E_0 e^{-(i-\beta)t} dt$$

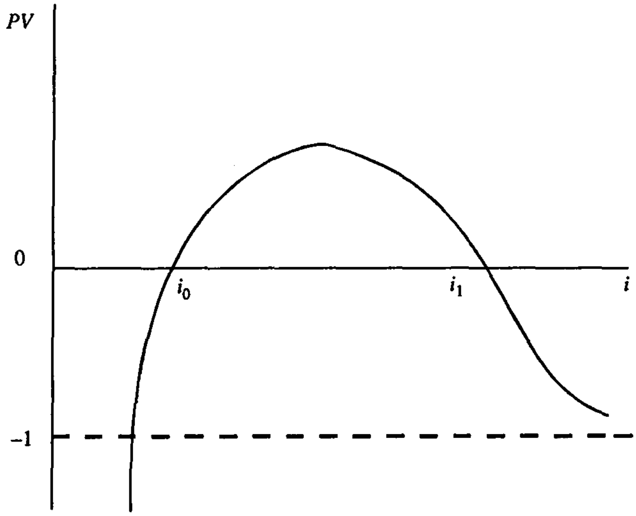
or

$$PV = -1 + D_0 / (i + \partial) - E_0 / (i - \beta) \tag{5}$$

The introduction of the two new parameters, β and ∂, has the effect of changing the shape of the PV and i. As figure 3 shows, for a development project to pass the PV test, the rate of discount must lie in the range between i_0 and i_1. For discount rates above i_1, the rea-

son why the PV test fails is that development benefits are too heavily discounted to offset the initial cost of the project. For $i < i_0$, the test fails due to the fact that the exponentially growing preservation benefits are so little discounted that the associated loss becomes too large in the PV calculation. This procedure is equivalent to adjusting the discount rate: a lower discount rate is applied to preservation benefits and a higher discount rate to development benefits. It can be concluded that for sufficiently low or sufficiently high discount rates, the PV will fail the PV test: the modified approach narrows the range of social discount rates for which a project is profitable.

Figure 3



The analysis has been developed considering the particular and relevant case that the condition for the existence of distinct real roots is met, that is: $\sqrt{D_0} > \sqrt{E_0} + \sqrt{\partial + \beta}$ (see Porter, 1982, for other possible shapes).

We can see this by taking the derivative of the PV function (5) with respect to i:

$$\frac{dPV}{di} = -\frac{D_0}{(i+\partial)^2} + \frac{E_0}{(i-\beta)^2} \tag{6}$$

If $E_0 > D_0$, (6) is positive. If, however, $D_0 > E_0$, then the derivative is positive for low values of i (but near β) and negative at high values of i; there is, therefore, a value of i which leads to a maximum value of PV, which occurs at:

$$i = \frac{\partial\sqrt{E_0} + \beta\sqrt{D_0}}{\sqrt{D_0} - \sqrt{E_0}} \tag{7}$$

with the correspondent maximum PV:

$$PV = \frac{(\sqrt{D_0} - \sqrt{E_0})^2 - (\beta + \partial)}{\beta + \partial} \tag{8}$$

The *PV* given by equation (8) is positive only if (9) holds:

$$\sqrt{D_0} > \sqrt{E_0} + \sqrt{\beta + \partial} \tag{9}$$

which states our first order condition to get a positive maximum for the *PV*.

The second order condition, obtained by taking the derivative of (6) and imposing it to be negative at the discount rate (i) associated with the maximum present value (*PV*), just states that $\sqrt{D_0} > \sqrt{E_0}$ and so, does not add any new information.

The consideration of environmental preservation benefits (E) is important, since these provide a sort of minimum value to the flow of development benefits (D) needed to justify a project. Moreover, the introduction in the analysis of the rate of growth of preservation benefits (β) and of the rate of decay of development benefits (∂) may turn into unprofitable seemingly profitable development projects.

The strict application of the model would be quite demanding in terms of information outside the project. Nevertheless, its usefulness does not depend on getting all the relevant information: instead, a very common procedure in cost benefit analysis has been to calculate the net development benefits of a project and then to ask what the value of preservation benefits would have to be for the development not to take place. On the other hand, the development of valuation techniques to value preservation benefits can help towards a wider utilization of the model. Section 6 will focus on the issue of techniques for valuing environmental preservation benefits.

4. The model under uncertainty

In the basic cost-benefit formulae presented so far, we have assumed that the costs and benefits are known whith certainty. If benefits and costs are random variables with known probability distributions, and if decision makers are risk-neutral, then using expected costs and benefits should be a reasonable procedure in any cost-benefit exercise. In the presence of risk aversion, expected values of the variables should be replaced by certainty-equivalent values. However, even if individuals are risk-averse, we are quite justified in using expected values of benefits and costs by the Arrow-Lind theorem (see Arrow & Lind, 1970). What this theorem argues it that the larger the group of individuals across whom the risk is spread, the lower is the risk per head and so, as the population becomes very large, public sector investment should be appraised using expected values for benefits and costs. Anyway, these considerations on uncertainty in cost-benefit analysis are also relevant in our model and, as the theme is a complex one, no attempt is made here to give a full exposition on it (see, for instance, Pearce & Nash, 1981). However, what need to be emphasized is that there is another source of uncertainty in the model that is due to the presence of irreversibility.

The model we have been discussing requires that a proper assessment of future benefits and costs is made. Expectations about benefits from both the development and the preserva-

tion alternatives are assumed not to change with the passage of the time. Clearly, this is not realistic, since people do learn. Probability distributions attached to costs and benefits change over time. Since irreversibility is an important feature of the model, the introduction of uncertainty has important effects which require changing investment criterion beyond the replacement of known values with their expectations.

The concept of option value has been central to solving the problem of uncertainty where there is irreversibility of development decisions (see section 2 on option demand). Basically, the idea is that people are willing to pay a premium to ensure the option of visiting a natural area in the future. The asymmetry of alternatives (one is irreversible and the other not) is crucial to establish the existence of an option value of preserving the environment. Basically, what happens is that with the passage of time new information on the benefits of the development/preservation alternatives is made available and the point is that this new information can only be used as an input to decision-making only to the extent that development has not already taken place. Thus, there is some value in refraining from a irreversible action that otherwise looks profitable. Arrow and Fisher (1974) and Henry (1974a, 1974b) have modelled this situation, which is briefly described in what follows.

Suppose a two-period time horizon. Let $S1$ and $S2$ be the fractions of an area to be developed, respectively, in the first and in the second period. Assume that $\mu 1$ is the benefit net of all costs, including environmental ones, from developing all of the area in period 1; $\mu 2$ is the corresponding (discounted) second-period benefit. Constant returns to any level of development or preservation are assumed. Suppose that $\mu 1$ is known at the start of the first period and that $\mu 2$ is a random variable with a known distribution. This random variable assumes the value $\mu 2 = \pi 1 < 0$ with probability q and the value $\mu 2 = \pi 2 > 0$ with probability $1 - q$, with expected value $E(\mu 2) > 0$. The problem is to decide the area $S1$ to be developed in the first period in order to maximize the expected value of the area, considering irreversibility. Two cases are considered: information and no information on $\mu 2$ will be forthcoming before the beginning of the second period. In the case of no further information on $\mu 2$ at the start of the second period, only $\mu 1$ will determine the choice of $S1$ and the decision rule would be: $S1 = 0$ if $\mu 1 < 0$ and $S1 = 1$ if $\mu 1 > 0$.

If further information on $\mu 2$ becomes available, the decision rule changes. In particular, suppose that $\mu 2$ will be known with certainty at the start of the second period. In this case, it is learned that either $q = 0$ or $q = 1$. If $q = 0$, $\mu 2 = \pi 2 > 0$ and $S2 = 1 - S1$. If $q = 1$, $\mu 2 = \mu 1 < 0$ and $S2 = 0$.

The expected value of the area at the beginning of the first period, when the value for $S1$ must be chosen, is then

$$\mu 1\, S1 + q\, \pi 2\, S1 + (1-q)\pi 2 = (\mu 1 + q\, \pi 1)S1 + (1-q)\pi 2 \qquad (10)$$

The decision rule is also of the type $S1 = 0$ or $S1 = 1$. However, $S1 = 1$ only if $\mu 1 > -q\, \pi 1 > 0$.

The interpretation of this last result is that, as new information is known at the start of the second period, first period benefits must exceed some positive number $(-q\, \pi 1)$, which stands for the value of preserving an option to use the environment. This result is due to the combination of irreversible development in the first period and improving information in the second period. Irreversibility carries an additional cost, the option value. What happens is that the expected benefits of an irreversible decision should be adjusted for the loss of option associated with the decision. In terms of the model we have been discussing, the option

value should enter as an additional component of the preservation benefits, even if decision makers are risk-neutral. The effect of irreversibility is thus to reduce the net benefits, which are then balanced against costs in the usual way.

To estimate the option value of a natural resource would require the knowledge of unquantifiable elements as, for instance, to give a figure for the value of genetic information contained in a tropical forest. However, the framework can be helpful to highlight the need of a cautious development policy in not yet fully known natural areas, even if the analysis will be necessarily incomplete.

5. The configuration of acceptable projects considering environmental preservation benefits

In this section, we will examine the profile of projects acceptable from the social point of view when growing environmental preservation benefits (*E*) are considered, as well as decaying development benefits (*D*) are included in the cost-benefit exercise. The objective here is to examine the sensitivity of the minimum development benefits (*D*) required to keep the project acceptable from the social point of view to changes in the parameters that enter in the modified cost-benefit analysis: the magnitude of environmental preservation benefits (*E*), the rate of growth of these benefits (β) and the rate of decay for development benefits (*D*). The minimum development benefits (*D*) to be estimated correspond to the limiting case of a zero *PV*. Also, as it can be argued that developing societies tend to use higher discount rates (see Markandya & Pearce, 1988), the results of our exercise are also assessed considering larger increases in the discount rate than those considered in the tables.

In a first instance, the impact of constant environmental preservation benefits (*E*) on the minimum development benefits to keep the project profitable is analysed. Following it, growing environmental preservation benefits (*E*) at different rates of growth (β) are introduced in the same exercise. Finally, in addition to these two, the rate of decay of development benefits (∂) is considered.

Basically, as it had already been suggested, the effect of the introduction of preservation benefits in the analysis is to make the passing rules for projects more stringent. Essentially, for a project to be acceptable from the social point of view, it had to generate higher development benefits, in comparison to the case that preservation benefits were not considered. This was expressed by the leftward shift of the curve drawn in figure 2, showing that at any discount rate, the *PV* had been reduced by the introduction of preservation benefits as a cost in the stream of the project and thus development benefits had to be larger to ensure a positive net present value. Considering the same stereotyped project presented before (investment of 1 unit generates a perpetual flow of *D* forever after), table 1 shows the minimum development benefits (*D*) required for a project to be socially acceptable at different discount rates and environmental preservation benefits (*E*).

Observing table 1, we see that increases in environmental preservation benefits (*E*) and in the discount rate (*i*) affect the minimum development benefits (*D*) in a linear way. More specifically, an increase in one unit of either the discount rate (*i*) or preservation benefits (*E*) has to be compensated by an equal increase in net development benefits (*D*) so that to keep the project acceptable from the social point of view. At higher rates of discount, as it often happens in developing countries, projects to be acceptable would have to generate larger development benefits.

Table 1
Minimum development benefits (D) considering environmental preservation benefits (E) for different discount rates (i)

	$E = 0.1$	$E = 0.2$	$E = 0.3$	$E = 0.4$	$E = 0.5$
$i = 3\%$	0.13	0.23	0.33	0.43	0.53
$i = 4\%$	0.14	0.24	0.34	0.44	0.54
$i = 5\%$	0.15	0.25	0.35	0.45	0.55
$i = 6\%$	0.16	0.26	0.36	0.46	0.56

Tables 2 and 3 show the minimum development benefits (D) required from our typical project when growing environmental preservation benefits (E) at different rates of growth (β) are introduced in the cost benefit analysis, considering, respectively as discount rates (i) 4% and 6%.

Table 2
Minimum development benefits (D) considering growing environmental preservation benefits (E) at different rates of growth (β)

	$i = 4\%$				
	$E = 0.1$	$E = 0.2$	$E = 0.3$	$E = 0.4$	$E = 0.5$
$\beta = 1\%$	0.17	0.31	0.44	0.57	0.71
$\beta = 2\%$	0.24	0.44	0.64	0.84	1.04
$\beta = 3\%$	0.44	0.84	1.24	1.64	2.04

Table 3
Minimum development benefits (D) considering growing environmental preservation benefits (E) at different rates of growth (β)

	$i = 6\%$				
	$E = 0.1$	$E = 0.2$	$E = 0.3$	$E = 0.4$	$E = 0.5$
$\beta = 1\%$	0.18	0.30	0.42	0.54	0.66
$\beta = 2\%$	0.21	0.36	0.51	0.66	0.81
$\beta = 3\%$	0.26	0.46	0.66	0.86	1.06

As a general remark, tables 2 and 3 show that the minimum development benefits (D) required for the social profitability of the stereotyped project are higher when the rate of growth of environmental preservation benefits (E) is introduced, comparing with the case that such rate is assumed to be zero. Increases in the level of the rate of environmental preservation benefits (E) require more than proportional increases in development benefits (D) to keep the project worthwhile, for a given discount rate. It is also true that the higher is the size of environmental preservation benefits (E), the higher will be the sensitivity of minimum development benefits (D) to changes in the rate of growth of preservation benefits (β). Moreover, table 3 compared to table 2 indicates the fact that a higher discount rate tends to reduce the size of the minimum development benefits (D) required from the project, since environmental preservation benefits (E) which enter as a cost in the benefit cost stream are being more heavily discounted. Notice, however, that at higher discount rates, say in the

range 10-20% and for low values for environmental preservation benefits (E), this is not true. Instead, the minimum development benefits increase as the discount rate increases, for a given level of E and β. For instance, at a value of i = 15%, E = 0,1 and β = 2%, D would have to be 0,27. This can be seen by taking the expression for D from equation (5) and taking its derivative with respect to i. Accordingly, we have:

$$\frac{\partial D}{\partial i} = 1 - \frac{E\beta}{(i-\beta)^2} > 0 \quad \text{if} \quad i > \sqrt{E\beta} + \beta \tag{11}$$

This means that for sufficiently high values for i, if E and β are not too large, as the higher is the discount rate, the higher will be the values for D. The combination of these specific values for i, E and β result in that projects to pass the present value test need to generate a higher income to be acceptable, contrarily to the conventional wisdow that high values for discount rates in development countries tend to make "too many projects" acceptable.

Our final level of analysis will be to add a rate of decay for development benefits (∂), also considering as discount factors i = 4% and i = 6%.

Basically, the introduction of a rate of decay for development benefits (∂) increases the minimum development benefits (D) required for a project to be acceptable. The other comments on tables 2 and 3 also apply to tables 4 and 5.

Table 4
Minimum development benefits (D) considering growing environmental preservation benefits (E) at different rates of growth (β), and different rates of decay for development benefits (∂)

	i = 4%				
	E = 0.1	E = 0.2	E = 0.3	E = 0.4	E = 0.5
β = 1% ∂ = 1%	0.22	0.38	0.55	0.72	0.88
β = 2% ∂ = 2%	0.36	0.66	0.96	1.26	1.56
β = 3% ∂ = 3%	0.77	1.47	2.17	2.87	3.57

Table 5
Minimum development benefits (D) considering environmental preservation benefits (E) at different rates of growth (β), and different rates of decay for development benefits (∂)

	i = 6%				
	E = 0.1	E = 0.2	E = 0.3	E = 0.4	E = 0.5
β = 1% ∂ = 1%	0.21	0.35	0.49	0.63	0.77
β = 2% ∂ = 2%	0.28	0.48	0.68	0.88	1.08
β = 3% ∂ = 3%	0.39	0.69	0.99	1.29	1.59

6. The nature of the basic parameters and their estimation

The modified approach to the cost-benefit analysis incorporating preservation benefits introduces three new parameters into the activity of project appraisal: E, β and ∂, as compared to the conventional approach which requires D and i.

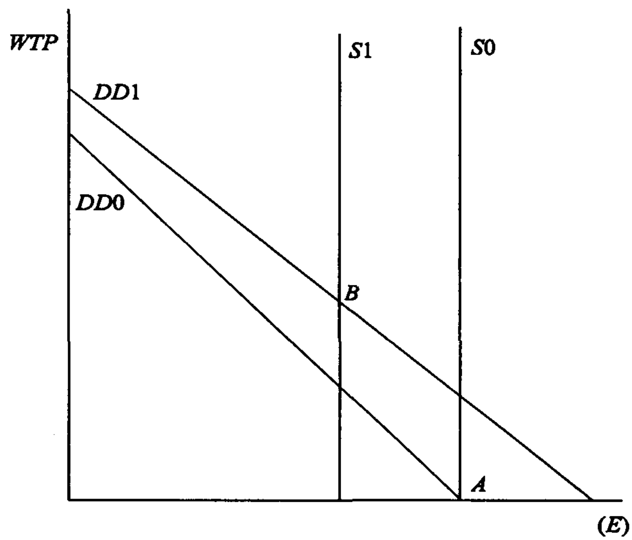
Environmental preservation benefits (E) of a site are defined as the sum of the components of what is called the total economic value (TEV) concept. This last represents the value imputed to the functions performed by environmental resources. As components, we have to distinguish between "user value" and "existence value". While the total user value component encompasses the value assigned to the actual use of the environment, both the actual and the option to it in the future, the existence value component represents the people's preferences for their existence. The option value, in the user value component, as was explained in section 4, would be the value of the environment as a potential benefit as opposed to actual present use value. It is an expression of willingness to pay for the preservation of an environment against some probability that the individual will make use of it at a later date. The existence value component stands for the value people put on the mere existence of an environment. For tropical forests, for instance, the user value component would include the value of timber and non-timber products, recreation of the site, the value of biodiversity, the ecological function associated with air pollution reduction, watershed protection, while the existence value component would include the value people put on the mere existence of this ecosystem (see Pearce & Turner, 1990).

A major problem in the valuation of environmental preservation benefits of a natural area is the lack of monetary expression for some of the components of the TEV. How to value, for instance, the biodiversity contained in a tropical forest? There are no easy ways to solve this problem. However, the recognition that it may be difficult to provide a value truely representative of both the user value and existence components should not prevent the project analyst from estimating the main components of the TEV of a resource. For example, a park that is used for recreational purposes by neighbourhood populations has as a main component of the TEV the willingness to pay of users to conserve the park. In this case, its preservation benefits could be estimated by the Travel Cost Method, by which preservation benefits are approximated by the travel cost users have to incurr to get to the recreation site (see Johansson, 1990). The use of this method as a legitimate one to estimate the TEV was first proposed by Hotelling in a 1947 letter to the director of the US National Park Service and it was based on the idea that the user must reasonably find the "commodity getting to the park" at least worth the travel cost. However, other components of the TEV do exist, as the existence value, which can be considered minor compared to the user value.

Leaving the interested reader in the specific valuation techniques to refer elsewhere (see Johansson, 1990), it can be anticipated that there has been progress in valuing nonmarketed environmental goods. Among these, the contingent valuation method by which people are directly asked how much they are willing to pay for a environmental improvement, or, equivalently, how much they require as compensation for an environmental deterioration (see Sarmiento, 1993) has proved successful in many contexts. The important point to be emphasized at this stage is that the attitude of completely disregarding the environmental preservation benefits (E) in a cost-benefit analysis because of the estimation intrinsic limitations of the various methods is untenable, since those benefits can be very large and incorporating them as a cost of the project may turn into unprofitable seemingly profitable projects.

The next important parameter is β, the rate at which the environmental preservation benefits are appreciating relative to development benefits. This rate depends on both the demand and the supply sides of the "market" for environmental resources. At the demand level, this rate would be affected by the expansion of the willingness to pay for wilderness activities in a particular area. It depends on the rates at which the vertical and the horizontal intercepts of the demand curve for that area are shifting outward (see Porter, 1982). It is reasonable to think that the high income elasticity of the demand for environmental activities and the continued reduction in the supply of substitutable preserved wild spaces will raise both intercepts. This situation is depicted in figure 4, where *DD*0 and *DD*1 stand for demand curves for environmental goods in period 0 and 1, *S*0 and *S*1 the supply curves in periods 0 and 1, respectively. The rate of growth for environmental preservation benefits (*E*) could be calculated using the willingness to pay information of the equilibrium points A and B (*WTP*).

Figure 4



This means that the number of potential users of a particular wilderness area grows for two reasons: from a general growth in wilderness demand and from a shrinkage in the size, quality, and number of alternative wilderness areas. It may be the case that for some wilderness areas, characterized by ecosystems under the threat of extinction, the parameter component reflecting their "depletion" may be of fundamental importance in the estimation of the rate of appreciation of preservation benefits.

The last new parameter in the modified approach to cost benefit analysis is ∂, the rate at which net development benefits are depreciating. This would require extrapolation of the expected trends of development benefits and costs. Also, the consideration of technical change factors should be introduced in this estimation. This parameter is the one whose estimation is the less controversial, although also a complex one.

Concluding, it has been shown that the introduction of environmental preservation benefits when they appreciate relative to development benefits alters the shape of the decision in the benefit-cost analysis framework. Moreover, it has been suggested that there are practical ways for the estimation of the fundamental parameters of the model. These should be

specific to the project's site and to the project's net output. However, the intrinsic estimation problems of the basic parameters of the model should not lead us to try to measure the unmeasurable. Instead, it is suggested that more careful cost-benefit analyses extended to environmental effects incorporating as much information as is available are undertaken.

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