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# The Discount Rate in Environmental Cost-benefit Analysis

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## ABSTRACT

*Environmental cost-benefit analysis compares an assessment the benefit of the abatement or containment of a particular form of environmental damage with the cost of the measures needed to attain that abatement or containment. It is in that context, as with other applications of cost-benefit analysis, usual to apply a discount rate. A number of relatively recent textbooks in environmental economics suggest that general economic theory provides a clear and well-established benchmark as to what this discount rate should be: some kind of 'average' of the market rate of interest. There are questions about that assertion in general. Our focus in this paper relates to a more specific problem: the relative scarcity of environmental resources in comparison to produced goods. A specific framework of analysis is offered in that context.*

## 1. INTRODUCTION

HERE THE MAIN general weaknesses of the contention that (some kind of average) of the prevailing market rate of interest, is a fair reflection of the social cost of spending money on combating environmental problems is briefly summarized. This sets the stage for the environmental application of Section 3.

The standard approach is to assume that the pre-existing situation is one where there is equilibrium between supply and demand in each market. The problem at hand is, by assumption, the only market distortion. The neo-classical assumption of equilibrium in each market implies that to produce more capital equipment for investment in a backstop technology requires a reduction in the demand for capital goods for other types of investment, i.e. public money must squeeze a so-far commercially attractive form of investment out of the private investment demand schedule. Obviously, if the neoclassical assumption of pre-existing equilibrium in each market is dropped in favour of the Keynesian assumption of a deficiency of demand in relation to the economy's physical capacity to supply, then a totally different perspective arises. The neoclassical assumption gives rise to the construct of a 'social opportunity cost of capital':

> The opportunity cost of the public sector project is the private sector project. (Common, 1996:335)

This view sets up the problem as the cost-benefit analysis of one single environmental problem in isolation from any other problems of natural resource depletion or environmental degradation. The question what the private sector project and its contribution to future material affluence is *for*, is not discussed any further. One does not have to accept the demand from people like Schumacher (1973) or Meadows *et al.* (1972, 1992) for zero growth in full, to nevertheless consider a lower, rather than a higher rate of economic growth in an already affluent country, desirable in order to mitigate a range of other environmental problems, provided full employment and social stability is maintained. Squeezing the construction of a factory that produces material affluence gadgets out of the supply of investment funds, for the sake of some green project, is a true social cost, only if we begin by assuming exactly that: the loss of growth of material wealth that arises out of not building the factory, is indeed a true social cost on account of loss of material affluence, even if employment and social stability is maintained either way. We now leave this more general point for what it is, and concentrate on the problem of cost-benefit analysis as it is traditionally defined: there is confusion even within the remit of that definition of the problem. Even if we accept that for projects of a material nature, including 'ordinary' public provisions on a non-commercial basis some kind of market assessment of the rate of interest is a fair measure of the cost, the problem of the relative scarcity of environmental resources is not considered. We offer a framework of analysis that considers this problem.

## 2. THE CONVENTIONAL RELATION BETWEEN UTILITY AND THE RATE OF INTEREST

The relation between the market-clearing rate of interest, savings and economic growth is conventionally based on a utility function. This utility function is here presented as:

$$W = \int_{t=0}^{\infty} e^{-\delta t}\, U(C_t)\, \delta t \tag{1}$$

(after Hanley and Spash, 1991, p.128).

Here $\delta$ ($\delta>0$) is the time-preference coefficient. $U$ then has the usual property that the next slice of affluence is not as valuable in terms of utility as the one that is associated with a preceding increase in $C_t$ of equal material quantity/money value:

$$\delta U_t / \delta C_t = \gamma U_t / C_t \tag{2}$$

where the coefficient $\gamma$ $(0 \leq \gamma < 1)$ is the marginal elasticity of increasing utility in relation to increasing affluence. The simplest underlying relation that produces these results is:

$$U(C_t) = (C_t)^{(1-\phi)} \tag{3}$$

The open closed interval $(0 \leq \phi \ \ 1)$ is the requirement that is needed to make the function both mathematically well-behaved and economically straightforward to interpret, but the open interval $(0 < \phi < 1)$ is the more usual assumption: the next slice of affluence is strictly less valuable in terms of utility than the previous one. These assumptions establish a relation between the utility function and the rate of growth of material affluence and the market clearing rate of interest (i), which is:

$$i = \delta + \phi\lambda \tag{4}$$

Here $\lambda$ is the prevailing rate of (*per capita*) economic growth:

$$C_t = (1 + \lambda) \ C_{t-1} \tag{5}$$

## 3. A TWO-SECTOR MODEL: MATERIAL AFFLUENCE AND ENVIRONMENT

Spash (2002 pp.221ff) argues that, whatever the conclusions in terms of economics, simply forgetting about the interests of future generations and considering problems such as global warming literally as a problem of *apres nous le deluge*, which is what any significant discount rate amounts to in practice, is wrong. One might well agree. It is, however, not self-evident that there is a need to invoke any issue of the superior morality that the government really ought to impose over the short-term greed of the citizens. We consider the issue of the relative scarcity of the material resources of the Earth, in comparison to produced goods that we can make. The conventional assumptions summarised in the previous section, relate to saving for future material affluence and the opportunity of individuals to acquire future affluence by saving now and having a higher income in the future. They do imply that saving and investing in the material sector of the economy now, rather than spending the money on cleaning up the environment, could cost a successor generation a lot of material affluence. Nevertheless, they do not imply that this rate of interest also is the relevant rate of discount in relation to spending money now to the benefit of future environmental conditions. Continued economic growth and its associated opportunity to invest in new equipment that incorporates higher (labour) productivity is driven by technical innovation. The current generation is, by the nature of having to do something (or nothing) now, in the position of having to make a decision on behalf of its successors. It is, however, a mis-statement of rationality to formulate this decision as a rational extension of the conventional form of cost-benefit analysis, thereby implicitly extending the usual technique of discounted cash flow as known from commercial investment analysis, to a problem on which it does not fit.

We get a more realistic treatment of the relation between technical progress and the appropriate rate of discount in evaluating environmental conservation or restoration projects, if we postulate a joint utility function:

$$J_t = J(C_t, E_t) \tag{6}$$

Here $C_t$ is current market-valued consumption, $E_t$ is the supply of (non-monetary) environmental benefits. The function $J$ as such is assumed to be homogeneous of degree one, any reference to time-preference and/or declining marginal utility with higher levels generally, as opposed to one factor being scarce relative to the other factor, needs to be expressed separately. The matching total utility function at decision time zero can then be allowed to have the usual properties of time preference and declining marginal utility.

We take the market rate of discount as it applies to material affluence and ordinary commercial transactions for granted, and concentrate on any difference of the market rate of interest and the appropriate rate of discount for environmental cost-benefit analysis. What matters is the relation between the rates of growth of $C_t$, material affluence, and $E_t$, the available amount of environmental services supplied by the finite Earth, and the elasticity of substitution between the two in their joint evaluation function $J$. That leaves any issue of the next slice not being as valuable as the previous one, ('declining marginal utility') as the only relevant role of $U$. As mentioned above, $J$ is assumed to be homogeneous of degree one, in the same way as a production function showing constant returns to scale.

Normally, the term 'elasticity of substitution' relates to production function theory. In that context, the elasticity of substitution explains the (change in the) ratio between the demands for two input factors (production factors), as a function of the (change in the) ratio between the prices. In the context of minimizing the cost of production for any given level of output, these are assumed to be the marginal products, the partial derivatives. Application of that definition to the joint evaluation function $J$ would mean that we divide the explained relative change in the two inputs $\Delta(C_t/E_t)/(C_t/E_t)$ by the matching relative change in the ratio between the two partial derivatives, $\Delta((\partial J_t/\partial C_t)/(\partial J_t/\partial E_t))/((\partial J_t/\partial C_t)/(\partial J_t/\partial E_t))$. Accordingly the elasticity of substitution, defined as explaining the change in the ratio between the two volumes is:

$$S = (\Delta(Ct/Et)/(Ct/Et))/(\Delta((\partial Jt/\partial Ct)/(\partial Jt/\partial Et))/((\partial Jt/\partial Ct)/(\partial Jt/\partial Et))) \tag{7}$$

We do not know the magnitude of the elasticity as defined above. What can nevertheless be done, is to delineate the logical limits of the relation of any decision, with the more usual type of cost benefit calculation. If the elasticity of substitution is defined to conform to (7) above, it is systematically negative: the increments in the ratios between the volumes have the opposite signs as those related to the prices. In practice, elasticities are routinely reported as absolute values. To maintain consistency, we refer to the elasticity as defined above as $S$, its absolute value is therefore $-S$.

In the present context, a non-trivial difference in interpretation arises. The logic is the other way round. The ratio between the two inputs $C_t$, the produced supply of material consumption, and $E_t$, the available supply of environmental resources, $(C_t/E_t)$ is the given explanatory variable, and the ratio between the two partial derivatives, which really ought to be the price ratio, $((\partial J_t/\partial C_t)/(\partial J_t/\partial E_t))$, is the explained dependent variable. Because of the effect of technical progress and continuing investment in the material market-economy sector of society, more and more material affluence arises and places demands on the Earth, but certain critical supply capacities of the Earth lag behind.

> The resources of nature, though apparently abundant in some ways, are in other ways manifestly limiting, sometimes to a dangerous degree (Price, 1993 p.295).

It has been argued that technological improvement in using the Earth more efficiently might, and, according to the evidence of the lack of increase in the prices of certain key minerals and agricultural products, have so far to a certain extent avoided and counterbalanced this problem. As the experience of collapsing fish stocks makes clear, there is first of all a problem of lack of market incentives for those resources that have no market and therefore no price. Secondly, as is becoming clear from our experiences with the global warming problem and a range of other pollution problems, the mirror-problem of getting rid of undesirable by-products of economic activities is becoming more acute than finding more resources in less accessible places. In addition, technological innovation and its associated big-scale mechanization, like for example being able to drill for oil under the ocean or under the frozen permafrost of Northern Alaska and Northern Siberia, also creates a potential for bigger disasters with things like tankers and pipelines.

That the Earth is finite and that any limit will in the fullness of time be reached with continued economic growth, is true by logic alone. The question whether the Earth also is finite on a time-scale that has meaning for the living generation and its concern for successor generations, is not the topic of this article. We proceed on the assumption that it is. In the present context it is more useful to present the ratio between supplies and the prices that would be a fair representation of scarcity, if there were any prices, in reciprocal form in comparison to (7), with the sign reversed:

$$-1/S = -(\Delta((\partial J_t/\partial C_t)/(\partial J_t/\partial E_t))/((\partial J_t/\partial C_t)/(\partial J_t/\partial E_t)))/(\Delta(C_t/E_t)/(C_t/E_t)) \qquad (8)$$

On the Finite Earth, our default assumption of no environmental degradation is $E_t^* = E_0$ (for all $t$), where $E_t^{**}$ is the naturally available supply of environmental services, not counting any man-made substitutes. This leaves room for economic evaluation of any ‘backstop’ technology, that mimics ‘producing’ environmental services, for example by building installations to produce windpower, solar power etc., instead of using greenhouse gas releasing fossil fuels. The balance relation for any environmental service therefore is $E_t = E_t{}^* + E_t{}^{**}$. Here $E_t{}^{**}$ is the amount of the same environmental service that has been produced by a backstop technology.

As long as the default assumption of $E_t{}^* = E_0$ is maintained, the growth rate of $(C_t/E_t)$ is the growth rate of $C_t$, the general rate of economic growth of material affluence. There is no need to specify whether the function $J$ is purely our joint evaluation of material affluence and the environment, or whether it also reflects the relative importance of environmental factors in specific and important sub-sectors of commercially measured production, such as for example the contribution of the atmosphere to the production of energy, or of fresh water to agriculture.

The economic meaning of the Finite Earth and the appropriate rate of discount in evaluating investments in a backstop technology, is now summarised in the following three cases. We maintain the simplifying assumptions outlined above, including a path of constant growth.

Case 1): The elasticity of substitution is central.

$$\begin{aligned} -1/S &= -(\Delta((\partial J_t/\partial C_t)/(\partial J_t/\partial E_t))/((\partial J_t/\partial C_t)/(\partial J_t/\partial E_t)))/(\Delta(C_t/E_t)/(C_t/E_t)) = \\ &\quad -(\Delta((\partial J_t/\partial C_t)/(\partial J_t/\partial E_t))/((\partial J_t/\partial C_t)/(\partial J_t/\partial E_t)))\ /(\Delta C_t/C_t) = \\ &\quad (1+\delta+\phi\lambda)/(1+\lambda) = (1+i)/(1+\lambda) \end{aligned} \tag{9}$$

Here -1/S, the reciprocal of the absolute value of the elasticity, is slightly above unity, at least in the normal $i > \lambda$ case. The growth rate in material affluence is $\lambda$. If the (absolute value of the) substitution elasticity was exactly one, then the growth in material affluence would cause the discounted price of environmental factors to fall slightly. The relative price of the scarcity of environmental factors as such would increase, but this increase would still be dominated by the discount rate. We therefore choose the central case as a somewhat lower absolute value of the elasticity of substitution that results in a somewhat higher sign-reversed reciprocal. It causes the ratio between the partial differential ratios $\partial J_t/\partial E_t$ and $\partial J_t/\partial C_t$ (the relative price that environment supplies ought to command, if they had a price), to grow at the rate $i > \lambda$, given that the rate of growth for the ratio between the two volumes is l. In the central case defined in this way, a cost-benefit analysis that uses current prices already discounts environmental resources at the rate $i$. The discounted price of environmental factors therefore stays put at its current value. No explicit discounting in environmental cost-benefit analysis is called for.

Case 2): The elasticity of substitution ($-S$) is high, with a low reciprocal.

$$0 < -1/S = -(\Delta((\partial J_t/\partial C_t)/(\partial J_t/\partial E_t))/((\partial J_t/\partial C_t)/(\partial J_t/\partial E_t)))/(\Delta(Ct/Et)/(C_t/E_t))$$

$$= -(\Delta((\partial J_t/\partial C_t)/(\partial J_t/\partial E_t))/((\partial J_t/\partial C_t)/(\partial J_t/\partial E_t)))/(\Delta C_t/C_t)) < (1+\delta+\phi\lambda)/(1+\lambda) = (1+i)/(1+\lambda) \qquad (10)$$

As economic growth takes place and $(E_t/C_t)$ becomes less on account of the increase in $C_t$, the ratio between relative price of the environment (if it had a paid price), would increase, but its growth rate would not be as much as the commercial rate of discount. The rate of discount in environmental evaluation is positive, but still less than what applies for commercial investment. The rate of discount that is applicable to environmental cost-benefit analysis becomes the same as the commercial rate of interest, only in the extreme case, when the elasticity of substitution is infinite, and $\Delta((\partial J_t/\partial C_t)/(\partial J_t/\partial E_t))$ is zero.

Case 3): The elasticity of substitution ($-S$) is low, with a high reciprocal.

$$-1/S = -(\Delta((\partial J_t/\partial C_t)/(\partial J_t/\partial E_t)) / ((\partial J_t/\partial C_t)/(\partial J_t/\partial E_t))) / (\Delta(C_t/E_t) / (C_t/E_t)) = -(\Delta((\partial J_t/\partial C_t)/(\partial J_t/\partial E_t)) / ((\partial J_t/\partial C_t)/(\partial J_t/\partial E_t))) / (\Delta Ct/Ct)) > (1+\delta+\phi\lambda) / (1+\lambda) = (1+i) / (1+\lambda) \qquad (11)$$

The rate of increase in the relative price of $E_t$ is higher than $i$, and a negative discount, an ‘upcount’ needs to be applied according to the excess. The investment in the backstop technology could be warranted, even if its commercial evaluation at present prices not only never recovers the cost of the initial investment, but also is negative in terms of operating cost. The commercial cost of producing the backstop product must be allowed to be more than the commercial operating cost of continuing to use and further destroy a scarce environmental resource, without considering that environmental resource as a financial cost.

In the extreme, when the elasticity of substitution moves to zero, i.e. $E_t$ and $C_t$ are complementary, then we do not tolerate any environmental degradation. Economic growth is tolerated only if the backstop technology is used and fully maintains a growth rate in the supply of environment factors that matches the growth rate of material affluence, whatever its cost.

The above summary refers to an unchanged amount of $E_t$. It assumes an initial situation of no production of $E^{**}$ by means of backstop technology. Except in the extreme cases of complementarity or infinite elasticity, it does not answer the question *how much* production of $E^{**}$ by means of backstop technology should take place. To answer that question, we obviously need to say more about the relationship between the cost of the backstop technology and the scale of its operation, and make specific assumptions about set-up costs, overheads, etc.

## 4. CONCLUSIONS

In the absence of specific information of how much a constraint on material affluence and its enjoyment by future generations environmental degradation really is, we are a long way from being able to ‘objectively’ assess whether it is worthwhile spending any particular sum of money on combating any particular environmental problem. Nevertheless, what we can say is that the usual way of calculating a cost of interest in cost benefit analysis, is at the extreme, infinitely elastic end of a range of logically defendable assumptions on that point.

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## ENDNOTES

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## REFERENCES

Common M (1996) *Environmental and Resource Economics: an Introduction*, Harlow: Longman.

Hanley N and Spash C L (1991) *Cost-Benefit Analysis and the Environment*, Cheltenham: Edward Elgar.

Meadows D L (ed.) (1972) *The Limits to Growth: A Report for the Club of Rome's Project on the Predicament of Mankind*, London: Potomac Associates.

Meadows D L, Meadows D and Randers J (1992) *Beyond the Limits*, London: Earthscan.

Price C (1993) *Time, Discounting and Value,* Oxford: Blackwell.

Schumacher E F (1973) *Small is Beautiful : An Economics as if People Mattered.* London: Bond and Briggs.

Spash C (2002) *Greenhouse Economics: Value and Ethics*, London: Routledge.