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On the "Environmental" Discount Rate[1]

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In this paper I show that "environmentalism" itself can provide a rigorous foundation for the low and declining discount rates that environmentalists seem to favor in long-term cost–benefit calculations. If indeed it is a stylized fact that we are moving toward a world where environmental spending is increasingly important, that scenario per se may significantly lower the social rate of return. A formula is derived for the ratio of social to private discount rates as a simple function of two operational environmental parameters. The formula is used to explain why the social rate of return ought to be lower than the private rate and why this gap—called "environmental drag" when measured in terms of equivalent evaporation of national income—may be expected to increase over time.

INTRODUCTION

Long-term discounting is a contentious issue in cost–benefit analysis. For many projects—particularly in the areas of energy, health, safety, and the environment—effects are often felt far into the future, sometimes across several generations. Global warming issues might be a prime example. At almost any reasonable discount rate, distant future effects do not very much influence the present discounted value of a project because they are drowned out by the force of compound interest, a result that many find disturbing.

Yet, there is a hidden assumption in such calculations. While the social discount rate being used has frequently been adjusted from the private rate to reflect various appropriate factors—indeed there is a huge literature on this subject[2]—it is almost always taken to be *constant* over time. Constancy of discount rates, however, is not an innocuous assumption. It implicitly amounts to assuming some stationarity over time. This may be a particularly inappropriate assumption for a world seemingly evolving toward an ever increasing degree of environmental concern.

In this paper I argue that the stylized facts about the evolution of environmental effects should imply a systematically lower social rate of return over time, thereby affecting not only the level of social discount rates but also their time profile. Environmental amenities can be viewed as a classical time-varying externality. At low levels of income and economic activity, environmental concerns typically represent a relatively low priority. However, as levels of income and economic activity rise, environmental effects become increasingly more important.

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[2]The survey in Lind [4] is quite comprehensive and contains many additional references to the subject. An earlier work that contains applications to environmental economics is Fisher and Krutilla [2].

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There are undoubtedly several reasons for this. One may be that greater economic activity typically results in disproportionately greater environmental degradation through pollution, habitat destruction, overcrowding, and the like. Another reason is that environmental amenities in general probably represent a luxury good with a relatively high income elasticity. Whatever the reasons, it seems fair to suppose that as an economy develops, the "terms of trade" turn in favor of the environment.

An externality varying with time in this way will cause the relevant social rate of return to decline over time. Although the essence of the argument is readily grasped, I do not think the full implications have been realized. By putting the right structure on the problem, it is possible to derive a quite tidy formula relating social and private rates of return. The social rate of return turns out to have the form of a multiplicative adjustment of the private rate of return, where the multiplicative adjustment coefficient is a simple function of two relevant environmental variables: the fraction of income spent on environmental improvement and the elasticity of response to it.

Alternatively, the basic formula of this paper can be interpreted as quantifying "environmental drag." Environmental drag is an insightful complementary way of looking at the "environmental" rate of return. Conceptually, environmental drag measures the lowering of the social rate of return due to environmental spending in terms of a fictitious "equivalent evaporation" of national income. The concept of environmental drag is useful for measuring the true social cost of environmental improvements. The "drag" comes from the lowering of the marginal product of capital, "as if" some output were evaporating. A very rough estimate of the degree of environmental drag on the United States economy is made and some implications are explored.

THE BASIC MODEL

In order to focus sharply on the relation between environmental externalities and the social rate of return, I assume no other possible distortions in the economy. There already exists a huge literature on why the market rate of return on private capital might not accurately measure true social opportunity costs for reasons other than those central to this paper.[3] In abstracting away from these other aspects, I do not mean to slight their possible importance. As a practical matter, it just does not make sense here to attempt some grand synthesis. Instead, I entertain the usual hope that some component of the "pure" environmental effect on the social rate of return highlighted by this paper will come across even through more complicated "mixed" settings.

For analytical tractability, I follow the tradition of working with a highly aggregated model. The assumptions that would allow for such aggregation cannot literally be true. But hopefully this is the best way of focusing sharply on an environmental effect that would survive more realistic treatments.

The economy is represented by a one-sector model, whose single output is a uniformly homogeneous good that can be divided readily among alternative uses.

[3] See the quite comprehensive survey in Lind [4] and the references cited there.

Having investigated some alternatives, I do not think the fundamental message is dramatically altered by working with a more complicated multi-sector formulation.

Suppose the usual notation: t stands for time, K stands for aggregate capital, I is aggregate net investment. Then we have

$$I(t) = K(t+1) - K(t). \tag{1}$$

The uniformly homogeneous single output is denoted Y, and the relevant reduced-form[4] aggregate production function at time t is

$$Y(t) = F(K(t), t). \tag{2}$$

Let C stand for ordinary, traditional consumption.

The variable D will stand for environmental disamenities such as pollution, crowding, and degradation of natural sites.

The level of environmental disamenity D can be lessened by expending resources on improving the environment. For specificity, these resources might be thought of as "cleanup" expenditures on pollution abatement or control, but a far more general interpretation is possible as total spending on all environmental improvement programs.

Let $\psi(t)$ represent the amount of national income spent on environmental improvement at time t. Then

$$C(t) + \psi(t) + I(t) = Y(t) = F(K(t), t). \tag{3}$$

Next, assume that the level of environmental disamenity per unit of economic activity at any time is a function of environmental spending per unit of economic activity at that time, of the form

$$\frac{D}{Y} = G\left(\frac{\psi}{Y}, t\right). \tag{4}$$

It is assumed that $G' \equiv G_1 < 0$ and $G'' \equiv G_{11} > 0$.

The above functional form (4) seems not unreasonable and will yield a crisp expression for the social rate of return. In effect, it is being assumed that environmental disamenity is a constant-returns-to-scale function of economic activity and environmental spending. Formulation (4) embodies the idea that pollution emitted per unit of economic activity is some function of pollution abatement spending per unit of economic activity. This seems like a decent approximation for, e.g., Y = number of automobiles, D = total emissions, ψ = total spending on abatement technology. The generalization to an entire economy seems innocuous

[4] In the present context, a "reduced-form" production function means that net output is written as a function of capital and time alone. All other variables that might matter, like labor or technological change, are assumed to be functions of time and hence can be aggregated into the reduced form (2). Provided that depreciation is proportional to capital stock, net output is just gross output minus the constant depreciation coefficient times capital.

enough at the appropriate level of abstraction relative to the sharpness of results that can be derived.[5]

The variable

$$Z \equiv \frac{\psi}{Y} \tag{5}$$

represents the fraction of national income spent on environmental improvement.

Now define

$$E(Z,t) \equiv -\frac{ZG'}{G} \tag{6}$$

to be the elasticity of environmental improvement with respect to environmental spending.[6] E represents the percentage by which degradation declines due to a 1% increase in environmental spending. As such, E is a measure of the *ease* of environmental improvement. The variables E and Z will appear as prominent parameters in the basic formula for the social rate of return.

An environmental program $\{C(t), D(t)\}$ is feasible if it satisfies (3) and (4) for all t starting from a given initial capital stock $K(0)$.

This paper seeks to characterize the social rate of return associated with a feasible environmental program. It should be appreciated that the approach is rather general in the sense that not much structure is being put on the form of an environmental program. The results to be derived do not even require the explicit specification of utility functions, much less a full-blown optimal growth model.

Let the *private* rate of return on capital in this model economy be denoted $i(t)$, or, in shorthand, $i = i(t)$. The private rate of return refers here to the interest rate that would be applicable if environmental concerns or restrictions were ignored. The private rate of return in a distortion-free economy is just the marginal product of capital, written symbolically as

$$i = F', \tag{7}$$

where F' is shorthand notation for the relation

$$F' \equiv F_1(K(t),t). \tag{8}$$

The main task of the paper is to demonstrate how the ratio of social to private discount rates can be derived as a simple function of the two environmental parameters Z and E and to analyze the implications of this relationship.

[5]Note that the present formulation treats environmental disamenities as a flow, dependent on the flows of current output and abatement spending. The treatment of stock disamenities, dependent on cumulative effects of past flows, yields quite similar results. If X stands for a stock disamenity, where $X(t+1) = X(t) + D(t)$, with the remaining structure being the same as that of the present paper, then identical results are obtained.

[6]E is not generally invariant to monotone transformations of the degradation function. In effect, E is defined for the particular degradation function satisfying condition (4).

THE ENVIRONMENTAL RATE OF RETURN

This section derives the social rate of return for the model economy described in the previous section.

We start with some *given* feasible environmental program and consider the hypothetical effects of small variations in the consumption–investment pattern.

Suppose, at time t, that consumption $C(t)$ were decreased by some small amount δ, which is then invested in extra capital formation. This causes output at time $t + 1$ to increase by

$$\Delta Y = F' \cdot \delta + O(\delta^2), \tag{9}$$

where $O(\delta^2)$ represents terms of order δ^2 or higher.

In the standard externality-free formulation, expression (9) represents the amount of extra consumption available for withdrawal at time $t + 1$ while leaving intact the rest of the program. Hence (9) forms the basis for identifying the (private) rate of return i with the marginal product of capital F'. However, when environmental effects are included, Eq. (9) must be appropriately amended to calculate correctly the social rate of return.

When output is increased during period $t + 1$ from $Y(t + 1)$ to $Y(t + 1) + \Delta Y$, environmental deterioration is also increased, other things being equal. If the rest of the program, including the level of environmental disamenities, is to be left intact from time $t + 1$ forward, then less extra consumption than is indicated by (9) can be withdrawn at time $t + 1$ because some additional expenditures on environmental cleanup will be required during period $t + 1$ to rectify the environmental degradation.

If the previous level of environmental amenities $D(t + 1)$ is to be maintained at time $t + 1$, then *extra* environmental spending $\Delta\psi$ must be expended during period $t + 1$ to offset the deleterious effects of increased output ΔY. The amount of the extra required environmental spending may be calculated as follows.

Suppressing superfluous notation wherever possible, the essential tradeoff between ψ and Y for constant D $(= \bar{D})$ can from (4) be expressed as

$$\bar{D} = Y \cdot G\left(\frac{\psi}{Y}\right). \tag{10}$$

Considering ψ in (10) as an implicit function of Y, written $\psi = \psi(Y)$, we can calculate ψ', the derivative of ψ with respect to *Y holding D constant*, by implicitly differentiating (10) with respect to Y, which yields

$$0 = G\left(\frac{\psi}{Y}\right) + YG'\left(\frac{\psi}{Y}\right)\left[\frac{\psi'}{Y} - \frac{\psi}{Y^2}\right]. \tag{11}$$

Expression (11) can be solved for ψ', obtaining

$$\psi' = \frac{\psi}{Y} - \frac{G}{G'}. \tag{12}$$

Making use of definitions (5) and (6), Eq. (12) can be recast as

$$\psi' = Z\left(1 + \frac{1}{E}\right). \tag{13}$$

From Taylor's approximation,

$$\Delta\psi = \psi' \cdot \Delta Y + O(\Delta Y)^2. \tag{14}$$

Finally, combine (9), (14), and (13) to obtain

$$\Delta\psi = Z\left(1 + \frac{1}{E}\right)F'\delta + O(\delta^2). \tag{15}$$

Now the *social* rate of return on consumption, denoted $r(t)$, is the extra *net* consumption available at time $t + 1$ from withdrawing a small unit of consumption at time t and otherwise maintaining the same feasible environmental program from time $t + 1$ onward. Extra net consumption is the difference between extra *gross* potential consumption ΔY and the incremental cleanup cost $\Delta\psi$ required to undo the extra environmental damage created by the increased output ΔY. In symbols,

$$r = \lim_{\delta \to 0} \frac{\Delta Y - \Delta\psi}{\delta}. \tag{16}$$

Combining (9) with (15) and passing to the limit, (16) becomes

$$r = F' - F' \cdot \left(Z\left(1 + \frac{1}{E}\right)\right). \tag{17}$$

Substituting i for F' from (7), Eq. (17) can be rewritten to express clearly the relationship between the social and private rates of return:

$$r = i\left[1 - Z\left(1 + \frac{1}{E}\right)\right]. \tag{18}$$

Expression (18) is the central result of this paper. A surprisingly simple formula relates the environmental rate of return r to the private rate of return i, which involves only the fraction of income spent on the environment, Z, and the elasticity of environmental improvement with respect to environmental spending, E. The right-hand-side variables i, Z, E are semi-operational in the sense that they are, at least in principle, knowable.

ON THE CONCEPT OF ENVIRONMENTAL DRAG

The purpose of this section is to interpret and analyze the basic formula (18). For this purpose it is convenient to rewrite (18) as

$$r = i(1 - \gamma), \tag{19}$$

where

$$\gamma \equiv Z\left(1 + \frac{1}{E}\right) \tag{20}$$

is a "correction factor" denoting by what proportion the private rate of return should be diminished to yield the appropriate environmental rate of return.[7]

Now the correction factor γ of (20) has an interesting heuristic interpretation as a coefficient of environmental drag. To see this interpretation, one should envision the process of economic growth as an allegory about deposits and withdrawals from an imaginary bank.

When more consumption is foregone this year, the act of increased saving translates, by capital accumulation, into greater future income, which can be withdrawn as extra consumption in future years. Suppose we conceptualize the extra future consumption as being carried away from the bank like so many silver coins in a bucket. Without environmental externalities, the bucket does not leak. The effect of imposing environmental standards is to lower potential future withdrawals of consumption, as if the bucket used for carrying away the withdrawn extra income were leaking. The fraction of extra potential consumption income lost through leakage might be taken as a measure of the degree of environmental drag imposed by the standards.[8]

To make the concept of environmental drag more precise, suppose the following thought experiment. Let one small unit of consumption be converted to savings and "deposited" this year. If there were no environmental standards, then i extra units of consumption could be withdrawn and carried away next year without otherwise affecting future consumption. Under current environmental standards, however, the bucket allows only r extra units of consumption income to be carried away. It is as if the bucket leaks or evaporates the fraction γ of its contents, where γ satisfies condition (20).

In the spirit of the above thought experiment, the correction factor γ defined by (20) might be called the coefficient of environmental drag. The remainder of this section analyzes the simple formula for γ given by (20).

Note that, other things being equal, the coefficient of environmental drag γ is greater as Z is larger or E is smaller. In all cases γ is bounded below by Z, so that the correction factor is at least the fraction of income spent on the environment.

When E is indefinitely large,

$$\gamma = Z. \tag{21}$$

When it is relatively easy to improve the environment, then the proportion of income spent on the environment is a relatively good proxy for the degree of environmental drag. In this case, all the adverse environmental consequences of increased economic activity are offset by greater environmental spending. The

[7]Note that the case $\gamma > 1$ implies a negative social rate of return to investment. This corresponds to a situation where society has overaccumulated capital and is overpolluting, to such an extreme degree that it would actually be better off divesting itself of some capital.

[8]Of course environmental standards yield benefits, too. Although this paper concentrates on the cost side, in the final analysis both sides should be balanced against each other.

lower social discount rate is signaling not that growth should be slowed, but that environmental spending should be increased.

However, when E is smaller and it is less easy to improve the environment, then any given proportion of income spent on the environment "counts" for more in the correction factor. The difficulty in substituting income as an offset for environmental degradation is signaling a higher underlying environmental drag than would be indicated by environmental spending alone. The economy cannot so easily undo environmental damage, implying a correspondingly lower social rate of return on investment for a given level of environmental spending. In this case, the lower social rate of return becomes a signal that the growth of economic activity should be slowed because of its adverse environmental effects, which cannot so readily be offset by increased environmental spending. In the limit when the elasticity of environmental improvement with respect to environmental spending is very low, even modest levels of environmental spending might indicate that a significant correction factor is appropriate.

It seems difficult to say how E might change over time; as a crude approximation it might be supposed that E is roughly constant. On the other hand, it seems reasonable to expect that the fraction of income devoted to environmental spending, Z, should increase over time with the stage of development. This might come about because greater economic activity typically results in disproportionately greater environmental degradation (measured in utility terms) through pollution, habitat destruction, overcrowding, and the like. Generally speaking, environmental amenities probably represent a luxury good with a relatively high income elasticity. In any event, it seems like a reasonable supposition that as an economy develops the fraction of income devoted to environmental spending should increase over time. Hence, as time passes we would expect the social discount rate to decline relative to the private discount rate.

Essentially, the social rate of return on investment decreases with the level of development because each extra unit of consumption is becoming less valuable relative to the negative externality of increased economic activity required to bring about the extra consumption. Such logic explains why the social or environmental rate of return might be expected to decline over time relative to the private rate of return. To the extent that it is an appropriate abstraction to assume constancy of any discount rate, it is probably the private rate of return. In that case, the environmental considerations of this paper argue in favor of a social rate of return that is not only lower than the private rate of return, but that is expected to decline systematically over time. If this argument is taken seriously, environmental considerations themselves argue in favor of using ever-lower interest rates to discount ever-more-distant future costs and benefits in social project analysis.

MEASURING ENVIRONMENTAL DRAG: AN APPLICATION TO U.S. DATA

The purpose of this section is to present some very rough empirical estimates of the coefficient of environmental drag for the United States economy. It should be emphasized that any numbers derived here are crude approximations indeed. Nevertheless, I feel such estimates may be useful in giving a rough handle on the "cost of clean" as defined by the lowering of the marginal productivity of capital due to environmental spending, measured in terms of an "equivalent evaporation" of national income.

Formula (20) for γ, the coefficient of environmental drag, is a function of two variables: Z, the fraction of national income spent on environmental improvement, and E, the elasticity of environmental improvement with respect to environmental spending. I obtain some rough estimates of Z and E as follows.

The United States Environmental Protection Agency has recently performed a systematic study which estimates total annualized costs for all pollution control activities in the United States as a percentage of GNP.[9] This number, which might be taken as a rough approximation of Z, rises from 0.9% in 1972 to 1.6% in 1981 to 2.1% in 1990 and is projected to grow to around 2.7% in the year 2000. It is tempting to think of this fraction as representing the "cost of a clean environment." Actually, as I have tried to emphasize in this paper, direct expenditures on environmental amelioration probably represent a considerable underestimate of true social cost of clean because indirect effects on lost growth are omitted.

To convert estimates of Z into estimates of environmental drag, we need to have some handle on the magnitude of the elasticity of environmental improvement with respect to environmental spending E. It is much more difficult to estimate E than Z. Some figures are available that indicate the approximate effects of environmental regulation by comparing actual emissions of major air pollutants with hypothetical projections of what they would be using 1970 levels of control.[10] Such figures, coupled with corresponding environmental spending numbers, loosely suggest values of E perhaps in a range of about 1/2 to 1. If this rough range were accepted, there is the implication from formula (20) that the environmental drag on the United States economy might be two to three times larger than the fraction of national income devoted to pollution control activities.

The estimates of E are so crude and incomplete that I do not want to probe much deeper in this direction because the relevant data are just not firm enough to support any more specific analysis. The topic is a worthy subject of more detailed empirical research when we can make firmer estimates of E. Nevertheless, even at this preliminary stage, I believe it is possible to have some sense of what seems to be occurring.

It seems likely that the drag on the United States economy of environmental improvements may be significantly larger than figures for direct spending might indicate. Environmental drag is perhaps two or three times greater than direct environmental spending. This would make current estimates of environmental drag more in the range of 4–6% of GNP rather than around 2%. If E holds roughly constant over time while Z continues to rise in the future at about the same pace that it has in the past, we might be talking about a fairly significant degree of environmental drag across a future period of, say, a half-century or more. Should this scenario come to pass, the social or environmental rate of return may be significantly lower than, and it may decline significantly more rapidly than, the private rate of return.[11] In such circumstances an economic outlook fundamentally different from today's might be implied.

[9] EPA [1, p. xvii].

[10] EPA [1, p. xx].

[11] Remember that what I am here calling the "private" rate of return is the rate that would be available to a hypothetical investor who can disregard environmental considerations or regulations.

CONCLUDING REMARKS

This paper presents a potentially new wrinkle on the old issue of finding the appropriate relation between the social rate of return and the private rate of return. The potentially new wrinkle concerns the impact of environmental considerations. A relatively simple formula is derived, which indicates that if environmental trends are extrapolated, then the social discount rate should decline systematically over time relative to the private discount rate. This finding of a systematic time pattern of increasing environmental drag on the appropriate rate of return may have implications for thinking about how to discount long-term projects over distant time horizons.

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