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ENVIRONMENTAL RISKS AND FUTURE GENERATIONS: CRITERIA FOR PUBLIC POLICY

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ABSTRACT: This paper examines alternative normative approaches to the policy challenges posed by long-term environmental problems such as toxic and radioactive waste disposal, stratospheric ozone depletion, and climate change. The paper argues that cost-benefit analysis is limited in its ability to handle the issues of intergenerational equity and uncertainty that are intrinsic to such problems. Also considered is the precautionary principle, which holds that policies should seek to reduce threats to the welfare of future generations if the costs of doing so would not significantly reduce the subjective well-being of existing persons. Although the precautionary principle depends on an explicit value judgement, it yields a policy criterion that is operationally decisive under a wide array of circumstances.

MASTER

INTRODUCTION

A broad class of environmental problems is characterized by the asymmetric distribution of benefits and impacts over time. Activities that generate toxic and radioactive substances, greenhouse gases, and other environmental insults yield perceived benefits to today's economy. But while wastes may be contained in steel drums, storage tanks, or underground depositories for some period of time, the possibility of their eventual release to the soil or water imperils persons who will live decades, centuries, or even millennia in the future. Similarly, greenhouse gas emissions have few immediate effects, but cumulative emissions threaten the long-term stability of the global climate system with potentially far-reaching implications for human and ecological systems.

The impacts of such long-term environmental threats are highly uncertain. Many products of modern technology do not exist apart from their manufacture by humans. Others, while naturally occurring, are today released by human activities at rates rivalling or exceeding the assimilation capacity of nature. As environmental scientist Wallace Broecker (1) pointed out, "[t]he inhabitants of planet Earth are quietly conducting a gigantic environmental experiment." Because we are perturbing the environment in a manner lying outside the range of historical experience or the capabilities of laboratory simulation, there can be no certainty regarding the impacts of climate change, the safety of hazardous waste storage, and so forth.

The example of stratospheric ozone depletion is instructive on this point. In the 1970s, simple calculations based on laboratory measurements showed that chlorofluorocarbons had the potential to deplete the ozone layer, but the magnitude of the effect was generally taken to be small. The discovery of the Antarctic ozone hole in the early 1980s at first baffled scientists. Subsequent research established that ice crystals embodied in certain Antarctic clouds greatly accelerate the rate of ozone depletion. The ozone layer thus turned out to be much less stable than the early calculations led us to believe.

Approaching the policy challenges posed by long-term environmental problems is controversial both in theory and in practice. Some argue that policies should be designed to equate the marginal costs and benefits of pollution abatement, measured in monetary terms. Others argue that the imposition of long-term environmental risks is morally unacceptable because it threatens the welfare of future generations. This tension is clearly evident in U.S. law. The National Environmental Policy Act, for example, recognizes "the responsibilities of each generation as trustee of the environment for succeeding generations," while the Clean Air Act explicitly forbids the consideration of cost-benefit criteria in promulgating air quality regulations. Executive Order 12291, on the other hand, requires that all federal regulations be evaluated using cost-benefit techniques unless countermanded by statute (2).

Untangling the issues behind this controversy is the focus of this paper. The paper begins with a discussion of cost-benefit analysis, outlining two characteristics that constrain its usefulness in the analysis of long-term environmental problems. First, the approach is blind to the distribution of impacts between social groups and between present and future generations. To the extent that issues of distributional equity are important to decision makers, this necessitates the use of explicit ethical criteria in policy formulation and evaluation. Second, cost-benefit techniques are generally ill-suited to the analysis of problems characterized by substantial uncertainty. In theory, cost-benefit analysis under uncertainty is a simple extension of well-established methods. In practice, the information requirements are often beyond the means of practical implementation.

As an alternative to cost-benefit analysis, the paper explores the implications of the *precautionary principle* as a normative approach to long-term environmental management under uncertainty. The precautionary principle is derived from the concept of sustainable development, and holds that policies should seek to reduce threats to future welfare if the costs of doing so would not significantly reduce the subjective well-being of present or future persons. This principle, like other normative criteria for use in policy analysis, rests on a particular value judgement. If one accepts this value judgement as reasonable, then one is left with a policy criterion that is operationally decisive under a wide array of circumstances.

THE THEORY OF COST-BENEFIT ANALYSIS

Cost-benefit analysis is rooted in a simple but compelling ethical proposition. By the doctrine of Pareto efficiency, a proposed policy change will lead to an improvement in social conditions if it benefits at least some members of society while leaving none worse off. Actual policy changes generally benefit some individuals but harm others, so this maxim would appear on the surface to have limited relevance to the real world. Suppose we define the net monetary benefit accruing to each individual as his or her net willingness to pay for a proposed policy change. If we assume that people are the best judges of their own well-being and that they are economically rational, a policy change will improve their welfare if they would be willing to pay a positive sum of money to put it into effect. Conversely, they would be injured if they would be willing to pay to *prevent* implementation of the policy. If the summed positive benefits accruing to the winners are greater than the summed "costs" or negative benefits incurred by the losers, then in principle the winners could compensate the losers so that the welfare of all individuals could be improved. Policy proposals that satisfy this standard, sometimes termed the Kaldor-Hicks criterion, are termed *potential Pareto improvements* and may in principle be identified using cost-benefit analysis.

A broad range of techniques have been devised to measure the net willingness to pay for proposed policy changes (3,4). In the simplest case, net benefits are measured by multiplying the change in the availability of each affected good by its price, assuming that no price changes are induced by the policy. Where the change is non-marginal so that not only quantities but also prices are affected, the appropriate indicator is the change in "social surplus," approximated in competitive markets by the area bounded by the market supply and demand functions between the initial and final quantities of the good (5).

A pervasive problem in cost-benefit analysis is the aggregation of costs and benefits that accrue at different points in time. Generally speaking, future benefits are worth less than those of the present since a dollar today may be invested to yield 1.03 dollars next year given a 3% interest rate. In neoclassical models of intertemporal equilibrium under perfect foresight, the interest rate constitutes a measure of an individual's marginal preference for consumption in sequential periods (6). This fact does not imply that people prefer the present to the future in any abstract sense — only that they optimize their consumption streams in a world of investment opportunities. In this sense, the discount rate is simply the price of future consumption relative to present consumption.

To express present and future benefits in comparable present-value units, net benefits that are realized t periods from the present are discounted by the factor

$$\delta_t = \prod_{i=1}^{t} \frac{1}{1 + r_i} \tag{1}$$

where r_t is the interest rate at date t and $\delta_0 = 1$. In the special case where the interest rate is constant over time so that $r_t = r$, this formula reduces to the more familiar $1/(1 + r)^t$. Suppose that C_t and B_t are the flows of monetary costs and benefits realized at time t as a result of the proposed policy change. Then the net present value (NPV) of the net benefits yielded by the proposed policy change is given by

$$NPV = \sum_{t=0}^{T} \delta_t (B_t - C_t) \tag{2}$$

where the current date is normalized to $t = 0$ and T is the final date at which the policy has economic impacts. If this quantity is positive, then the policy change constitutes a potential Pareto improvement and is said to yield net positive benefits in the sense that the policy could in principle be implemented along with appropriate income transfers so that all members of society would be rendered better off. It is well-recognized, however, that a *potential* Pareto improvement need not constitute an *actual* Pareto improvement. If policy implementation benefits some individuals at the expense of others and no compensation follows, the logic supporting cost-benefit analysis breaks down. Potential Pareto improvements constitute unambiguous opportunities for improved social welfare only if the "losers" are duly compensated.

Cost-Benefit Analysis and Distributional Equity

A distinguishing characteristic of cost-benefit analysis is its marriage to the baseline. All of the variables that go into a cost-benefit calculation — the cost of pollution abatement, the associated environmental benefits, and the discount rate — are reflections of anticipated economic conditions. The future path of the economy is not, however, fixed in stone but is instead of matter of collective choice. Should we as a society use the resources at our disposal to maximize our own selfish gratification without regard to the welfare of future generations? Should we act so as to ensure that the life opportunities of our children and grandchildren are equivalent to or better than our own? Either choice is possible and either may be pursued with consummate economic efficiency. Yet the efficient balance between the costs and benefits of pollution abatement might vary sharply under the two scenarios.

Consider, for example, the case of a long-lived pollutant generated by current human activities. Suppose for simplicity that the future costs imposed by the pollutant vary in linear proportion with economic activity. Then strong economic growth would raise pollution damages relative to a low-growth scenario at each point in time. As we have seen, the discount rate appropriate for use in cost-benefit analysis is equal to the marginal return on capital investment in the absence of market distortions. Economic growth is fueled by capital investment, with the rate of capital accumulation involving an equity decision concerning the level of wealth we wish to transfer to future generations. Increased accumulation implies a decrease in the marginal return on investment and hence a reduction in the social discount rate. Together, higher impacts and lower discount rates imply that it would be efficient to abate pollution more aggressively in a high-growth world than in a low-growth alternative.

This argument rests on particular theoretical and empirical assumptions and is rather informal in character. It is possible, however, to illustrate similar results using formal models rooted in the theory of intertemporal general equilibrium. Focusing on the issue of climate change, for example, Howarth and Norgaard (6) showed that cost-benefit techniques may be used to identify efficient greenhouse gas emissions profiles in a hypothetical overlapping generations economy. The efficient outcome, however, depends strongly on the degree of caring for the future, with an efficient world of deplorable living standards and high pollutant levels for future generations ours for the choosing should we so desire.

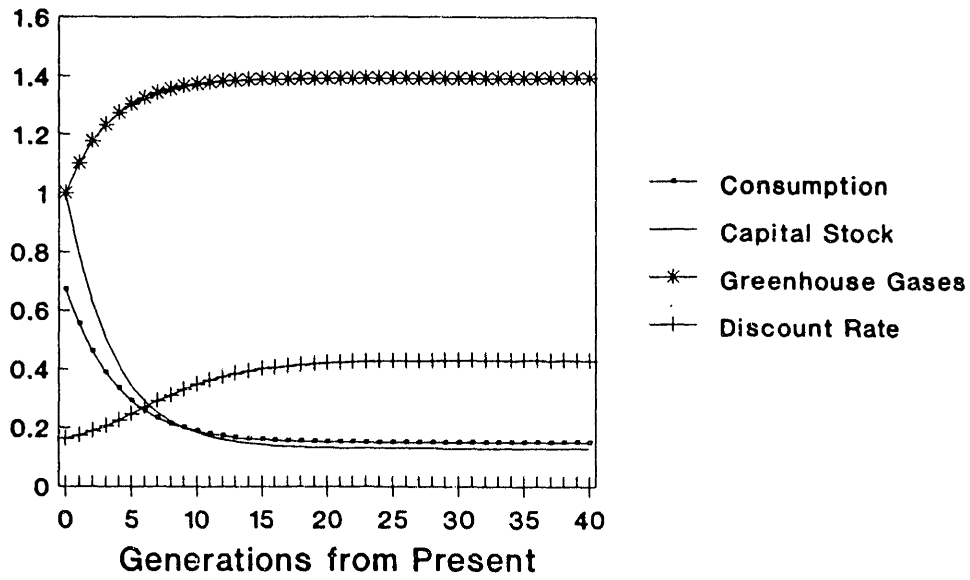
While the details of the Howarth-Norgaard model need not concern us here, a review of its results provides some insight into the subject under discussion. Figure 1 shows the levels of key economic variables — per capita consumption, the capital stock, greenhouse gas concentrations, and the social discount rate — for two model runs. The "impoverished future" case assumes an ethical framework in which present society cares little for posterity and thus depletes capital assets and adds substantially to the stock of greenhouse gases. The "sustainable future," in contrast, assumes that the present generation preserves capital goods and environmental quality for the sake of future generations. In each case, cost-benefit criteria are applied to identify an efficient greenhouse gas emissions profile. The two differ in the transfers of assets that are effected from one generation to the next, equivalent to transfers of wealth from the rich to the poor motivated by concerns about social justice.

The use of cost-benefit procedures will lead to an efficient response to long-term environmental threats only if the analyst correctly anticipates the future course of the economy. This represents a logical paradox since the "all else equal" assumptions of partial analysis are of limited relevance in an environment where all policy variables are subject to simultaneous choice. As Dasgupta and Heal (7, p. 257) pointed out, an economic future "can be intertemporally efficient and yet be perfectly ghastly" if it denies future generations the physical and cultural conditions required too sustain a satisfactory way of life. These facts should give us pause for thought about the use of cost-benefit analysis to identify an "optimal" response to problems such as waste storage, ozone depletion, and climate change in a world where issues of intergenerational equity are perceived to be at stake.

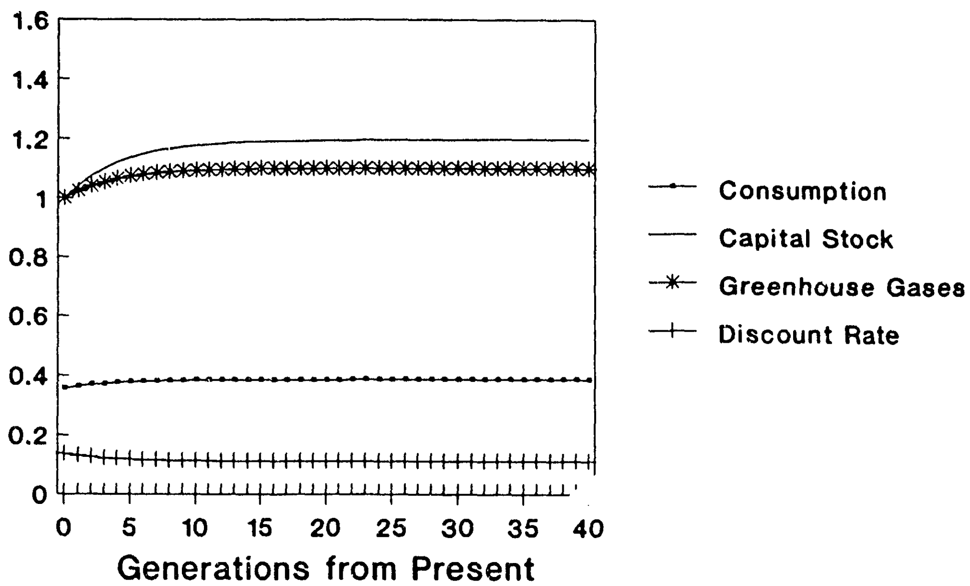
It is sometimes argued that scientific and technical progress are paving the way to a world of future abundance, obviating the need to consider questions of intergenerational equity in the analysis and promulgation of public policy. Indeed, the centuries since the Industrial Revolution have been marked by profound improvements in living standards driven by fundamental transformations in the interrelationships between technology, social institutions, and the natural environment. But trends are not destiny, and one cannot safely assume that conditions will improve in the future simply because they have improved in the past. Some now argue that the trend towards economic progress has already reversed and that today's young people will be unable to match the standard of living achieved by their parents in the absence

Figure 1: Alternative Future Worlds

(a) Impoverished Future



(b) Sustainable Future



of policy intervention (8). The question to ask is as follows: Is the present generation contributing to the technological base and preserving the capital and natural assets required to sustain the future welfare in light of anticipated technological progress and emerging environmental constraints?

Ours is the power to confer a world of poverty or abundance to the members of future generations, and there is no guarantee that events will turn out favorably in the absence of careful planning regulated by the adoption of suitable planning criteria.

Cost-Benefit Analysis and Equity Between Contemporaries

The focus of this paper is on the issue of intergenerational equity as it relates to environmental policy analysis. This focus, while helpful for purposes of exposition, is in truth a bit artificial in character. Environmental impacts, after all, are not distributed uniformly amongst contemporaries. Typically it is the weak and the vulnerable who bear the largest burden. For example, exposure to hazardous waste will fall disproportionately on the poor who must live next to waste storage facilities for want of the resources necessary to rent a home in a more desirable neighborhood. Similarly, the individuals most adversely affected by climate change are likely to be residents of low-income nations lacking the means to adapt favorably to changing climatic conditions.

Conventional cost-benefit techniques place equal weight on net monetary benefits that accrue to contemporaries regardless of their relative welfare. This runs against our moral intuition, for many would argue that a dollar spent on the poor yields benefits of greater moral worth than a dollar spent on the rich. In theory, issues of equity could be redressed through the transfer of wealth from rich to poor. In practice, however, disparities of wealth are likely to persist; is it then acceptable to impose environmental burdens on the weak so that the affluent may enjoy marginal benefits? Although such transfers of wealth from poor to rich might pass the test of Pareto efficiency, they are difficult to defend on moral grounds.

In principle, we need draw no distinction between fairness amongst contemporaries and fairness between present and future generations. Principles of justice between contemporaries logically define obligations to even the distant future (9). In practice, this means that we need to focus not only on the timing of impacts but also on their distribution between social groups.

Cost-Benefit Analysis and Uncertainty

Analyses of the potential costs and benefits of proposed environmental policies often focus on expected outcomes, averaging across low and high impact scenarios to obtain an estimate of the most likely sequence of events. In the face of substantial uncertainties, such a focus is not entirely appropriate. Our intuition informs us that fire insurance is a good investment even though we hope and expect that our homes will never burn down. Put another way, individuals will often give up expected benefits to protect themselves against the possibility of entailing large losses.

One approach to cost-benefit analysis under uncertainty is to use *ad hoc* procedures to adjust expected outcomes to account for risk. A standard argument is that individuals demand higher expected rates of return on investments yielding risky benefit streams in comparison with secure investments such as long-term government bonds. Thus cost-benefit analysts sometimes apply high discount rates in evaluating uncertain projects. While such an approach is simple to apply in practice, in theory it is rather objectionable (10). Theory informs us that a rational investor will demand a high expected rate of return on an uncertain investment if its returns are positively correlated with the return on her/his overall investment portfolio. Conversely, she/he will accept comparatively low (or even negative) expected returns on assets that provide insurance by yielding high returns when the market as a whole turns sour.

To illustrate the difficulties inherent in the problem, it is helpful to outline the formal criterion used to determine whether a policy offers a potential Pareto improvement when its outcome is uncertain. Suppose that there are n(t) possible outcomes or "states of nature" at date t denoted s_{ti} for $i = 1,\ldots,n(t)$. The probability of each state is $Pr(s_{ti})$. If the policy yields the net benefit $B_{ti} - C_{ti}$ under state s_{ti} at date t, the policy yields a potential Pareto improvement if the present-value expression

$$NPV = \sum_{t=0}^{T} \sum_{i=1}^{n(t)} Pr(s_{ti}) \delta_{ti} (B_{ti} - C_{ti}) \qquad (3)$$

is greater than zero (11). The discount factor δ_{ti} deserves special comment. In general, this factor varies across time and states of nature, accounting simultaneously for individual preferences concerning both time and risk. Each contingent future is linked to the present by its own state-contingent discount factor. The discount factor depends on individuals' risk aversion and on their relative well-being at sequential dates and under alternative states of nature.

It is clear that enormous quantities of information would be required to rigorously evaluate the costs and benefits of proposed policy interventions given substantial uncertainty. Consider the case of a long-lived pollutant with the potential to cause catastrophic harm to members of future generations. To decide on an efficient level of pollution abatement, we would need to know the complete range of possible future states, including their statistical probability, environmental impacts, and implications for human welfare. We would need to gauge social preferences regarding time and risk, even for low-probability, extreme outcomes for which we have little hard information to fall back on. It is not difficult to see that this approach is generally inoperational — we cannot with confidence identify efficient policy responses to long-term environmental problems where uncertainties loom large.

Where does that leave cost-benefit analysis as an approach to environmental policy? We can use crude information to get some feeling for the expected impacts of environmental insults as well as the probability of extreme change. We can reasonably speculate that society would be willing to spend extra resources to mitigate the threat of potentially catastrophic risks. But the appropriate sum to pay is beyond the reach of economic analysis and thus depends on the exercise of raw value judgements regarding what is acceptable and what is not.

SUSTAINABILITY AND THE PRECAUTIONARY PRINCIPLE

The class of problems under discussion has potentially far-reaching but uncertain consequences for the distribution of welfare between present and future generations, yet cost-benefit techniques are inherently ill-equipped to address issues of equity and uncertainty. How then should we proceed in the formulation and evaluation of policy? One possibility is to posit the existence of a social welfare function as a means of comparing and evaluating alternative strategies based on the comparative welfare of present and future generations across the complete range of possible outcomes. In principle, a social welfare function would simultaneously cope with questions of equity and uncertainty by reducing social values to a single, well-defined criterion. In actuality, efforts to define an appropriate welfare function have proved inoperational for well-known theoretical and practical reasons (12). Even if the presumed welfare function were within our grasp, its application to compare alternative policies would run up against the same information requirements that confound cost-benefit analysis under uncertainty.

We are left then to identify alternative criteria that capture prevailing notions of intergenerational justice under uncertainty. To gain some insight into this problem, it is important to note that the notion of intergenerational equity as it is usually put forth in public debates over environmental policy takes the form of a *constraint* on the range of outcomes that are considered ethically permissible rather than a utilitarian definition of "optimal" distribution. As the criterion is usually stated, economic development should be *sustainable* in the sense that the utilization of natural resources and the environment by the present generation does not jeopardize the ability of future generations to enjoy a favorable standard of living.

A number of definitions of sustainability and sustainable development have appeared in the literature. Consider, for example, the following selections:

> "The sustainability criterion suggests that, at a minimum, future generations should be left no worse off than current generations" (13, p. 33).
>
> "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (14, p. 43).
>
> "A sustainable society is one that satisfies its needs without jeopardizing the prospects of future generations. Inherent in this definition is the responsibility of each generation to ensure that the next one inherits an undiminished natural and economic endowment" (15, pp. 173-4).

These definitions are rooted in the common principle that present and future generations are ethically equivalent although they are not contiguous in time. Hence morality requires that members of future generations have equal or better opportunities than the present generation to live the good life in the same sense that it mandates an equitable distribution amongst the current generation. More so, in fact, since one might argue that while some degree of distributional inequality within a generation might be justified by the relative merits of individuals — the rich may have *earned* their wealth while the poor may have brought poverty upon themselves — it is difficult to argue that future generations are as a group less deserving than the present. To argue otherwise would be to discriminate against future generations based on the arbitrary happenstance of their birth dates.

Some philosophers, on the other hand, maintain that the present is in general under no obligation to provide a resource-rich world to future generations, or at least that such obligations are very weak. Schwartz (16; see also 17), for example, has argued that even minor policy changes intended to improve the lot of future generations would change not only the welfare but also the composition of future generations. Hence we are unable to affect the living standards of a well-defined set of future individuals; instead, we are choosing whether to bring relatively rich or relatively poor individuals into existence. If we take as our assumption that an action is morally mandated only if it benefits some individual who will actually exist, then this argument seems to force the conclusion that beneficence to future generations is not morally required unless the future world is so poor that the lives of future generations are not worth living.

Does this argument undermine the ethical basis of the sustainability criterion? Suppose that we define distributional equity as follows: All individuals, both present and future, should have an equal opportunity to pursue their own welfare. According to this criterion, a non-sustainable development program may harm no particular future individual but nonetheless be morally wrong on the basis that it gives rise to an unjust welfare distribution (18,19,20,21,22).

Schwartz's line of reasoning is open to another powerful critique. Children are born into this world helpless but for the benevolence of their parents and society generally. Each generation and the next overlap in time, and from a parent's perspective children are not future contingencies but rather facts of day-to-day existence. Most would agree that parents are under a strong obligation to provide their children with life opportunities at least equivalent to their own. For parents and their living offspring are morally distinct only in the happenstance of their birthdates, and it would be unjust for parents to pursue their own selfish interests at the expense of their children simply because their age and familial authority empowered them to do so.

Although the identities of unborn persons remain undetermined, our children will be obligated to *their* children once they are born and become flesh and blood. Thus our actions must ensure our children a favorable existence while permitting them to honor their obligation to their offspring. By logical extension, this argument defines a chain of obligation between the present and the indefinite future to ensure that living standards are non-declining from generation to generation. We owe it to our children, who will owe it to their children, and so on as far as the mind can see (9).

But even if sustainability is not deducible from prior ethical principles, it is nonetheless of direct policy relevance to the extent that it reflects the distributional values of the current generation. Indeed, the available evidence as reflected by the proclamations of politicians and related indicators of public opinion points to a high degree of concern in the body politic for the welfare of future generations.

The success of the sustainability criterion as a guide to policy analysis depends critically on the translation of these general precepts into operational planning criteria. But while there may be agreement on underlying values, there is considerably less on the implications of these values for intertemporal planning. As Lele (23) pointed out, the term "sustainable development" will devolve into a meaningless catch-phrase unless it is carefully and operationally defined.

Neoclassical economists have interpreted sustainability as a technical requirement that the utility or welfare of successive generations should be no lower than that of their predecessors. Pezzey (24), for example, explored the implications of the sustainability criterion for simple models of intertemporal development, reaching the conclusion that sustainability is a constraint that allows some degree of flexibility in intertemporal planning (see also 25). The present generation may choose any path that provides a constant or increasing level of welfare.

This approach runs against some of the same problems confronting social welfare analysis. By what standards, for example, are we to assess the welfare of future generations? One practical approach might be to define sustainability as non-decreasing per capita consumption. Under this standard, sustainable paths will exist whenever constant consumption paths are technically feasible. But aggregate economic indicators are notorious for their neglect of non-market environmental amenities and the degradation and depletion of natural resource stocks (26). Application of this approach will thus at a minimum require a careful reconsideration of conventional accounting techniques.

An alternative approach to the definition of sustainable development focuses on the conditions required to support a high standard of living into the indefinite future rather than the distribution of welfare across generations *per se*. Thus sustainability implies that we should ensure "the ability of future generations to meet their own needs" (14) or that future generations inherit "an undiminished natural and economic endowment" (15). This approach does not require an exact definition of the welfare of future generations. But it does imply an obligation to conserve environmental quality for the benefit of future persons.

A second issue is rooted in the inherent uncertainty concerning the future course of economic development. Policy makers are in fact choosing a probability distribution of potential outcomes, not a single well-defined path for the economy. Thus the question of risk is fundamental to intergenerational resource policy. How far are we willing to go to protect future generations against the *possibility* of an inhospitable world? As is argued above, the composition of future generations will depend on the state of the world prevailing when they are born. The individuals alive at a particular date under alternative contingent states should thus be regarded as ethically distinct *potential* generations, and sustainability would seem to require that the welfare of each potential generation be equal to or greater than that of its predecessor. Thus, in a world of uncertainty, the sustainability criterion may require sacrifices on the part of the present generation not only to raise the expected welfare of future generations but also to ensure that living standards are non-decreasing even under the worst of circumstances (27).

This is a strong supposition that needs to be placed in the context of competing social values. Few would argue, for example, that fifty percent of world income should be diverted to the construction of a planetary defense system to protect against the slight risk that future generations would be left destitute following a collision between the Earth and a large asteroid. On the other hand, the world community has decided to incur significant costs to reduce the uncertain threat posed by ozone depletion in the upper atmosphere. At a bare minimum, the sustainability rule suggests the moral obligation to take steps to reduce threats to future generations if so doing does not noticeably impact the subjective welfare of existing persons. This rule, termed the *precautionary principle* (28,29), calls for the general reduction of risks to future welfare, and mandates above all that we provide future generations with the flexibility required to adapt to unforeseen and unforeseeable events.

APPLICATIONS OF THE PRECAUTIONARY PRINCIPLE

To get a sense of the operational significance of the precautionary principle, it is helpful to state the principle in clear and explicit terms:

(P) *Inhabitants of today's world are morally obligated to take steps to reduce catastrophic risks to members of future generations if doing so would not noticeably diminish their own quality of life.*

Whether one accepts or rejects this principle involves a value judgement, and revised versions of the principle may be proposed. Malnes (30, p. 62), for example, argued that the present generation is obligated to "revoke risky activities that jeopardize future needs for the sake of less urgent contemporary interests ... well beyond the minimum requirements of subsistence." This matter is a question of social ethics that is best resolved through the political process mediated by the moral convictions of the participants rather than through technical analysis. A case may be made, however, that *P* or some related principle is both morally plausible and a reasonable reflection of prevailing social attitudes towards environmental risk.

Consider the application of this principle to the following sets of facts:

(1) A certain pesticide reduces losses for a number of crop species, thus yielding small improvements in farm profitability. While the immediate health risks of using the chemical are small, cumulative use leads to irreversible groundwater contamination that scientists believe may cause serious birth defects and childhood cancer fatalities. A substitute technology is available that would eliminate these risks yet impose a small increase in the price of some fruits and vegetables.

(2) Chlorofluorocarbons (CFCs) released to the atmosphere deplete the stratospheric ozone layer, increasing the proportion of ultraviolet-B radiation reaching the Earth's surface. Because CFCs accumulate and persist in the atmosphere for nearly a century, today's emissions will have a disproportionate impact on future generations. Impacts on human welfare are uncertain but are thought to include increased deaths from skin cancer and potentially serious damage to agricultural and natural ecosystems. CFC substitutes are readily available but would impose modest cost increases in certain products and processes: refrigeration systems, air conditioners, aerosol sprays, and the manufacture of electronic goods.

(3) Anthropogenic emissions of greenhouse gases such as carbon dioxide and CFCs threaten to raise global temperatures and alter weather patterns in unpredictable but potentially alarming implications for the welfare of future generations. Impacts might include sea-level rise, storm intensification, increased frequency of droughts and floods, reduced agricultural yields, mass species extinctions, disturbance of natural ecosystems, and increased prevalence of tropical diseases. Stabilization of current climatic conditions would impose large social costs. But steps to limit cumulative warming to no more than 2°C could be taken without noticeably reducing the subjective well-being of present or

future persons (31,32).

Under each set of facts, the requirements of the precautionary principle are clear: The government should act to reduce risks to future generations by banning the use of hazardous chemicals that yield trivial benefits, phasing out the production of CFCs, and imposing policies that reduce anthropogenic emissions of carbon dioxide. Whether such recommendations would follow from the application of conventional cost-benefit analysis is difficult to determine. In all likelihood we could not confidently quantify the impacts of these environmental insults even in physical terms. Monetization would then constitute a leap into the unknowable, rendering cost-benefit analysis inoperational for the cases under discussion.

In embracing the precautionary principle, we simplify the task of policy analysis and render it operational by reducing it to a two-part test: Does a particular environmental insult impose catastrophic risks on members of future generations? Can we take steps to reduce those risks without substantively compromising our own well-being? Within this framework, there is ample room for the application of economic and technical analysis. But objective analysis is a tool to be used in the identification and characterization of policy impacts, not a substitute for the properly subjective elements of arriving at a decision.

It is important to bear in mind that the "catastrophic risks" of the precautionary principle are risks to particular persons and may or may not entail threats to the general integrity of social or environmental systems. We might imagine a future world that is on the whole considerably richer than our own. Yet it would be wrong for us to impose crippling burdens on some number of its inhabitants for the pursuit of minor benefits to ourselves. A child born with a serious birth defect has no power over her destiny, and it is difficult to conceive of remuneration sufficient to compensate her parents or herself for her injuries. Nor can we claim that she would have been willing to accept the risk of deformity in exchange for offsetting benefits under more favorable circumstances. For a person's moral identity is contingent on the circumstances of her birth. The deformed person, born undeformed, would be an entirely different person by genotype and sense of personhood.

Or suppose that our emissions of greenhouse gases would leave a particular peasant society destitute by undermining the climatic conditions required to sustain fruitful agriculture. Even if the welfare of our own descendants were not at risk, the precautionary principle holds that we would be obligated to abate emissions, aid peasants to reduce their vulnerability to climate change, or both — provided that such actions would not noticeably reduce our subjective well-being.

The strengths of the precautionary principle include its informational economy and explicit foundations in normative values frequently articulated by participants in debates over environmental policy. As we have seen, the approach is often helpful in evaluating long-term environmental problems characterized by substantial uncertainty. In itself, the precautionary principle is a partial guide to policy that is best considered in the context of other planning criteria. In this sense, the approach challenges policy analysts to adopt a strategy of methodological pluralism (33,34), weaving together the insights gleaned from complementary scientific, ethical, and economic frameworks to achieve a synthetic view that is greater than the sum of its parts.

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