Chapter 9

Risks Of The Uncertainty Of Nature

Introduction

The risks inherent in the uncertainty of nature manifest themselves through extreme events: volcanoes; tsunamis; or meteorological extremes. Meteorological events, such as severe storms, tropical cyclones or drought, then produce consequences such as flooding, in the case of storms, or bushfires, in the case of drought. There is a well-founded statistical framework, known as the theory of extreme events (Gumbel, 1958), that provides a unifying basis for their mathematical treatment. This theory relies strongly on the extremal types theorem (Leadbetter et al., 1983) which shows that, when extreme values are drawn from a probability distribution, the resulting probability distribution of the extreme values is one of only three distributions.

The theory of extreme events led to the concept of a return period (or recurrence interval). When annual extreme values are analysed an event that has a probability of occurrence of 0.5 has a return period of 2 years, an event that has a probability of occurrence of 0.1 has a return period of 10 years, and so on. The theory has found numerous practical applications, especially in civil engineering, where it is used to design the height of dams and bridges, the size of culverts and the form of buildings in tropical cyclone prone areas.

The Australian region is the continent most subject to hydrological extremes. The risks associated with these extremes are being monitored continually and the Bureau of Meteorology has in place a sophisticated system of risk communication based on weather forecasts and alerts. These systems have been set up to deal with hazards that have occurred before and are, to a certain extent, familiar. (Beer et al., 1993).

The risks associated with climate change may be novel, in two ways. Present climate models indicate greater climate variability as a result of global warming. This variability will lead to more extreme events of certain types — more floods (Whetton et al., 1993) and more bushfires (Beer & Williams, 1995). In addition, there are risks associated with climate change arising from the uncertainties inherent in the atmospheric and societal response to global warming (Shlyakhter et al., 1995). These raise philosophical issues as well as issues of risk management. After reviewing risk management techniques, the topic of climate change will be considered as a case study of the risks of the uncertainty of nature.

Risk Management

Risk management is the process of forming and implementing a strategy for accepting or mitigating identified risks. It involves evaluating alternative policy options and selecting among them. The United States risk assessment framework of Fig. 3.2 separates, and maintains a clear distinction between, risk management and risk analysis. Once risk assessment moves out of the toxicological area, it is difficult to maintain such a neat distinction. Cox et al. (1994) point out that

> *"The separation of science (risk analysis) and economic and social welfare policy (risk management) on the basis that science deals with facts while economics deals with values is unrealistic and illusory. A clean separation is not possible. The recognition and acknowledgment that facts and values are often inseparable gives a human perspective to the technical nature of risk assessment."*

We agree. They also review the major frameworks used to regulate risk, identifying five. These are:

- Standards

Standards are a centralised process of setting permissible levels of an environmental hazard with the incentive for compliance being liability or a fine. Their advantage is that technological decisions are used to construct a uniform threshold of acceptable risk. The major drawback is that no attention is usually paid to the costs of implementation.

- Taxes and charges

  Market-based mechanisms, such as taxes, tradeable emission permits and subsidies, seek to achieve risk reduction targets by changing the financial incentives faced by individuals in dealing with risk. The emphasis is on economic efficiency by minimising nett costs to society.

- Cost effectiveness

  This seeks to find the least costly method of achieving a pre-determined risk reduction target. The target may be set on some other basis, usually through the political process.

- Benefit-cost analysis

  This is a tool to determine the economic efficiency of various policy options. It attempts to measure the costs associated with risk reduction and the subsequent welfare benefits from that reduction. The nett benefits or costs of policy alternatives are then compared to determine if, and to what extent, the risk will be reduced. The methodology is hampered by controversial issues such as putting explicit values on life and health. Other issues of concern include the choice of a discount rate and equity considerations.

- Information programs

  The provision of information through hazard warnings, labelling and risk communication programs is another market-based framework that may correct perceived market failures. The major benefit is that individuals can make informed choices based on preferences towards risk rather than being forced to accept uniform government bans or regulations.

CASE STUDY: Climate Change

There is no disagreement with the fact that measured atmospheric ambient concentrations of carbon dioxide have been increasing since the time of the industrial revolution. This gas plays a major role in absorbing long-wave radiation which is emitted by the earth and thus plays an important part in maintaining the temperature of the atmosphere. This absorption of long-wave radiation that is given off by the earth is known as the greenhouse effect. The concern related to climate change is that the indisputable increase in the concentration of carbon dioxide will lead to increases in temperature that are greater than those that have previously occurred and that these increases in temperature will then produce changes to the whole atmospheric circulation regime, possibly resulting in dramatic and undesirable impacts.

The issue of the greenhouse effect came into public prominence in the late 1980s. There has been concerted international action on the problem through the Intergovernmental Panel on Climate Change (IPCC), which brought together international groupings of scientists to assess the relevant science, the likely impacts, and to study the appropriate response. The justification for studying this problem in such detail is the precautionary principle. In addition, a second justification underlies much of this work, though it is less often mentioned in the context of climate change. This is the principle of intergenerational equity.

Principles of Environmental Policy

The May 1992 Intergovernmental Agreement on the Environment (IGAE),which was signed by the heads of Australian Governments, contains a summary of the principles underlying environmental policy. These principles are as relevant to the problems associated with climate change as they are to other environmental problems. The

Agreement states that, in order to promote sound environmental practices and procedures, there are four principles that should inform policy making and program implementation:

- precautionary principle;
- intergenerational equity;
- conservation of biological diversity and ecological integrity; and
- improved valuation, pricing and incentive mechanisms.

Precautionary principle
The precautionary principle, as stated in the IGAE, states that:

> *Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.*

The IGAE further states that, in the application of the precautionary principle, public and private decisions should be guided by:

(i) careful evaluation to avoid, wherever practicable, serious or irreversible damage to the environment;

(ii) an assessment of the risk-weighted consequences of various options.

Intergenerational equity
The present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations.

Conservation of biological diversity and ecological integrity
The IGAE states that conservation of biological diversity and ecological integrity should be a fundamental consideration.

Improved valuation, pricing and incentive mechanisms
Environmental factors should be included in the valuation of assets and services.

Polluter pays i.e. those who generate pollution and waste should bear the cost of containment, avoidance, or abatement.

The users of goods and services should pay prices based on the full life cycle costs of providing goods and services, including the use of natural resources and assets and the ultimate disposal of any wastes.

Environmental goals, having been established, should be pursued in the most cost effective way, by establishing incentive structures, including market mechanisms, which enable those best placed to maximise benefits and/or minimise costs to develop their own solutions and responses to environmental problems.

Aims of the case study

This case study aims to address the following questions:

1. What form of assessment of the risk-weighted consequences of climate change has been undertaken, as required under the precautionary principle?
2. Reducing the risk due to climate change requires actions on the basis of some combination of environmental integrity, equity or economic efficiency as measured by cost-benefit analysis. Is the concept of intergenerational equity consistent with cost-benefit analysis?

Climate Change and the Precautionary Principle
The issue with respect to climate change is that human activities may already be inadvertently changing the climate of the globe, through the enhanced greenhouse effect, by past and continuing emissions of carbon dioxide and other gases that will cause the temperature of the Earth's surface to increase — a possibility that is generally

termed 'global warming'. If this occurs consequent changes may have a significant impact on society.

The work of the IPCC is the major attempt to provide an ongoing assessment of the risk-weighted consequences of climate change. The IPCC was established by the World Meteorological Organisation (WMO) and the United Nations Environmental Programme (UNEP) in 1988 to:

(i) assess the scientific information related to the various components of the climate change issue and what is needed to evaluate the environmental and socio-economic consequences of climate change;

(ii) formulate realistic response strategies for the management of the climate change issue.

The panel established three working groups on the science of climate change, the impacts expected from climate change, and the response strategies to climate change. The first assessment made by these working groups was reported in 1990 (IPCC 1990 a,b,c), but the process is ongoing and there have been two-yearly supplementary reports issued.

The working group particularly charged with the responsibility of looking at the consequences of climate change was the impacts group (Working Group II). The method that was used was to study the scientific literature and determine likely and plausible scenarios for the state of the atmosphere as a result of climate change. As emphasised by Pittock (1993), a climate scenario is a description of a possible future climate developed for some given purpose and based on a number of assumptions. It is not a prediction. One of the main tasks of the impacts assessment was to determine vulnerabilities, namely, what aspect of the biosphere is most susceptible to the impacts of climate change. Some of the conclusions from the impact assessment are that:

- those communities of the natural terrestrial ecosystem which are most at risk are those with limited options for adaptability (e.g. alpine communities) and those communities where climate changes add to existing stresses;
- change in drought risk represents potentially the most serious impact of climate change in agriculture at both regional and global levels; and
- the most vulnerable human settlements are those especially exposed to natural hazards.

Options for a response to climate change fall into three categories — prevention, mitigation or adaptation.

- Prevention consists of tackling the problem at the source by implementing measures to reduce greenhouse gas emissions
- Mitigation aims to lessen the impacts of climate change by finding ways to assist vulnerable areas. An example of this would be the substitution of an existing crop with a strain able to cope better with the expected weather extremes arising from climate change.
- Adaptation,or even retreat in extreme cases, consists of learning to live with climate change and its consequences.

The risks associated with climate change are sufficiently severe that there is concerted international effort, exemplified by the Framework Convention on Climate Change (FCCC), to set up mechanisms to reduce greenhouse gas emissions. Adaptation measures are also being implemented in case there are adverse impacts. Detailed mitigation measures are not amenable to forward planning until more detailed predictions of climate change are available.

The precautionary principle

Cameron (1993) has identified what he sees as three core questions involved in the precautionary principle:

1. What counts as serious environmental damage ?

2. What measures are justified as regulatory action ?
3. How should questions (1) and (2) be determined ?

The first question is particularly relevant when some eco-systems and human communities may, because of their physical circumstances, face greater risks (in the form of threat of damage) than others from the same global phenomenon. In this way, if an international regulatory standard is introduced, it might be less precautionary for some communities than for others. Cameron (1993), in fact, cites the case of Pacific Small Island States.

> *"These will be very seriously and possibly fatally affected by the consequences of small changes in temperature, especially in relation to coral bleaching and sea-level rise. Efforts to prevent a sea level rise are therefore for these island communities barely precautionary; the threat to these islands is known with considerable certainty. This stresses environmental interdependence. The physical survival of certain communities is dependent on other communities behaving in a precautionary fashion."*

An important issue among the science community is what constitutes full scientific certainty. The above paragraph quotes a lawyer (Cameron) who asserts that the consequences for the Pacific Islands is known with considerable certainty. Scientists intimately involved in the area agree that there is certainly a risk, but are uncertain about the certainty — citing uncertainty about its magnitude and imminence. Scientific certainty is 'almost an oxymoron', to quote Robinson (1993). A more pragmatic approach sees scientific certainty as a function of: (i) the derivation of an acceptable confidence level in scientific work through statistical validation and analysis; and (ii) the acceptability of the work through widespread consensus (or peer review) by, for example, publication in scientific journals (McDonnell, 1993).

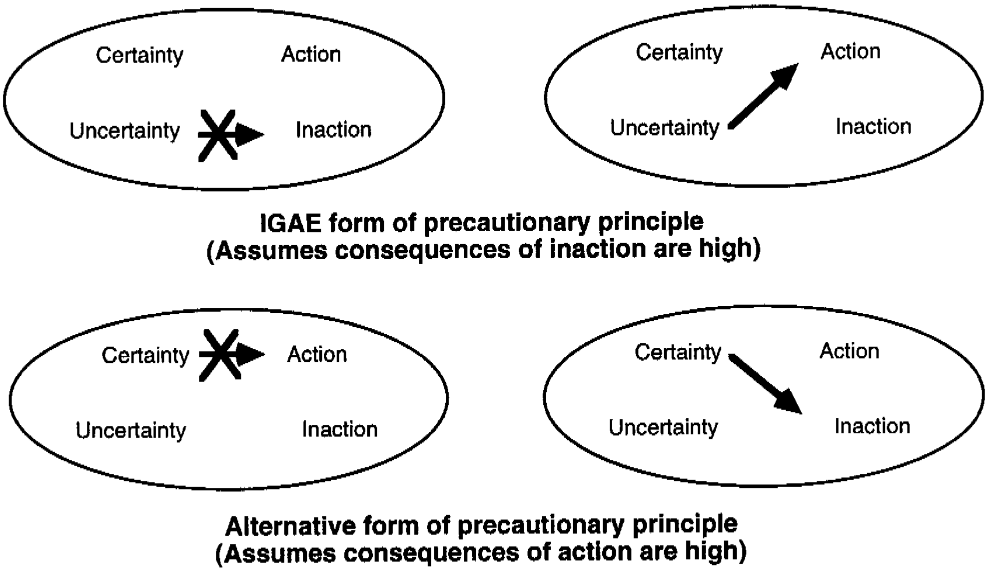
The mammoth process instituted by the IPCC produced reports that would satisfy the above two points, yet it would be virtually impossible to find a scientist who would be bold enough to claim that, therefore, full scientific certainty exists about climate change. Indeed, much of the scientific basis for the scenarios comes from computer modelling running general circulation models. Yet with the rapid evolution of computing power, the present state-of-the-art in computer models (e.g. Alcamo, 1994) will soon be discarded as it becomes possible to run general circulation models with smaller grid sizes, or more vertical levels, or with better representations of the physical processes.

This debate on scientific certainty hardly matters. There is agreement: that the atmospheric carbon dioxide concentration is increasing; that the laws of physics and chemistry predict that changes in the carbon dioxide concentration should be accompanied by changes in the atmosphere; and that there is a possibility that these changes will produce serious or irreversible environmental damage.

Baker (1992) notes that public perception on the climate change issue was galvanized by testimony to the US Senate in 1988 that drew the probable causative link between well-documented greenhouse gas increases and recent warming trends in globally-averaged temperature records. The national and international media, in reporting these remarks, omitted the concepts of probability and causation that were so carefully stated in the original Senate testimony. This predicament poses a dilemma recognised by Immanuel Kant: — concepts without perceptions are empty; perceptions without concepts are blind. Science provides the vision for otherwise blind, perception-based action. Or to rephrase these ideas of Baker (1992) into a risk assessment framework: the perceived risk should be based on the actual risk.

The application of the precautionary principle to climate change reflects its application to a global issue. There seems little argument about its role there. There is, however, extensive argument concerning its role in local issues. Cox et al. (1994: p. 40) use the example of the Superfund, given in Chapter 3, to point out a possible conflict. If a risk assessment indicates that capping, fencing and monitoring a contaminated site is the most cost-effective and efficacious option then such actions would be in contradiction to the criteria for the final state of the sites being set at the precautionary level (defined as soil sufficiently clean so that a well producing potable water could be dug in the middle of it). Australia, not being subject to legislation as inflexible as the US Superfund legislation, does not have such a problem. The IGAE form of the precautionary principle justifies action in the face of uncertainty, but instructs one to use a risk-weighted approach to determine the options.

Figure 9.1 Two Possible Forms of the Precautionary Principle



The IGAE form of the precautionary principle combines two negatives: 'lack of certainty' and 'not be used'. This has been simplified in Fig. 9.1 to indicate that the IGAE form of the precautionary principle implies that, if the consequences of inaction are high, one should initiate action even if there is scientific uncertainty. Many of us were taught in primary school to convert two negatives into a positive. This may be good English, but it is poor logic. In this case it leads to the assertion that scientific certainty should be used as a reason for postponing measures to prevent environmental degradation. Fig. 9.1 depicts this alternative form of the precautionary principle as implying that if the adverse consequences of action are high, then one should be inactive, even if there is scientific certainty. The following is under consideration in a growing number of international forums as a definition of yet another form of the precautionary principle.

> *Appropriate preventive measures must be taken when there is reason to believe that substances or energy introduced into the environment may or are likely to cause harm, even when there is no conclusive evidence to prove a causal relationship between inputs and effects.*

The alternative form of the precautionary principle (Fig 9.2) is invoked when people distrust experts. For example, conservation organisations invoked the precautionary principle during a meeting in March 1995 while discussing the discharge of contaminated water from the Ranger Uranium Mine. In this case, there is as close as one can get to scientific certainty from the Supervising Scientist that the discharge would not be harmful to health or to the environment. Nevertheless, the precautionary principle was invoked during discussions to argue that the release should not take place in case some unforeseen harm occurred. The IGAE permits action when there is a possibility that the consequences of inaction will be high. It does not condone inaction when there is a possibility that the adverse consequences of action will be high.

In the above situation there seems little doubt that the precautionary principle, as a legal principle, did not apply. The case study given by Prokuda (1993) is more debatable. Queensland Nickel wished to build a mooring for ore carriers close to a

Marine Park in North Queensland, and within the 'general use A' zone of the central section of the Great Barrier Reef Marine Park. The Great Barrier Reef Marine Park Authority (GBRMPA, the lead agency) refused the application, citing three areas of uncertainty:

- uncertainty about the quantity of ore that might spill during operations;
- uncertainty about the toxic effects of leachates; and
- uncertainty about the ore dispersion characteristics in the event of a spill.

Queensland Nickel appealed to the Commonwealth Administrative Appeals Tribunal and in terms of evidence for the appeal it advanced its initial EIA by investigating further the relevant issues with numerous expert reports. During the tribunal proceedings, GBRMPA introduced the precautionary principle into the proceedings. To quote Prokuda (1993) "the discussion...demonstrated what appears from the literature itself namely, that the principle is something of a moving feast and appears to have a life of its own."

Both sides agreed with a version of the principle that the assessing authority must be reasonably persuaded that a decision, particularly an irreversible one, will not have unacceptably large impacts. What was contentious was whether the decision maker needs to be satisfied beyond reasonable doubt that the proposed activity will be conducted in a manner that will not lead to harmful effects on the environment. The case was settled beforehand with the result that this issue remains unresolved.

Intergenerational Equity

The concept of intergenerational equity also underpins much of the present concerns about climate change. Climate change and, especially, sea level rise will be a slow process and present actions to avert a potential climatic catastrophe aim to protect future generations more than they aim to protect present generations. This is illustrated in Figures 9.2 to 9.4 (Pittock, pers. comm.) which use future CO_2 stabilisation scenarios and the expected temperature responses (Wigley, 1995) to determine the expected sea level change by the year 2500 for global climate sensitivities to doubled carbon dioxide corresponding to 1.5 to 4.5 degrees (Fig. 9.2), and the likely trends in sea level from the years 2100 to 2500 in the case of CO_2 stabilisation of 450 ppm and 750 ppm, shown in Figs. 9.3 and 9.4 respectively.

Figure 9.2 Sea level change by the year 2500 for different IPCC CO_2 stabilisation scenarios and climate sensitivities (From Pittock, 1993)

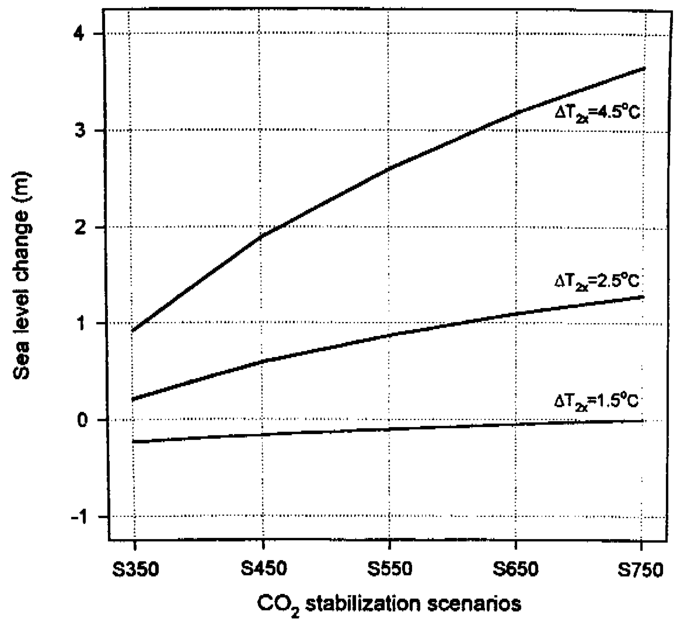


Figure 9.3 High (H), Medium (M) and Low (L) Sea Level Changes for the 450ppm Stabilisation Case. (From Pittock, 1993)

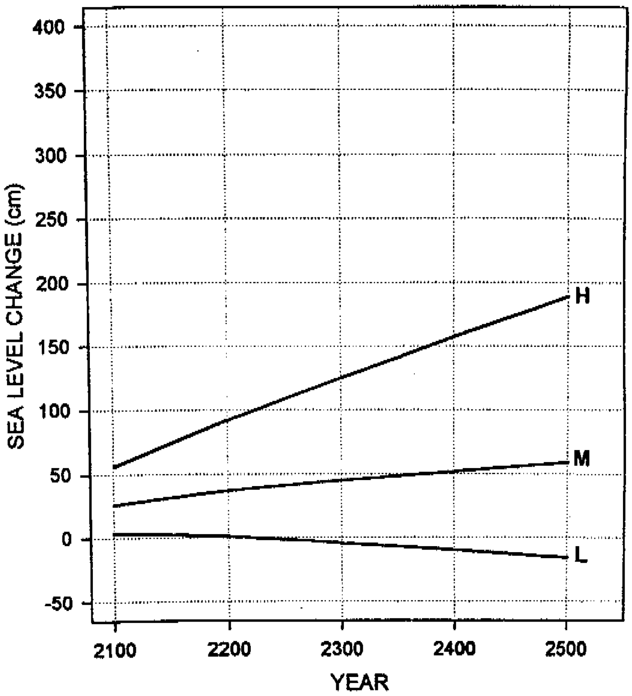
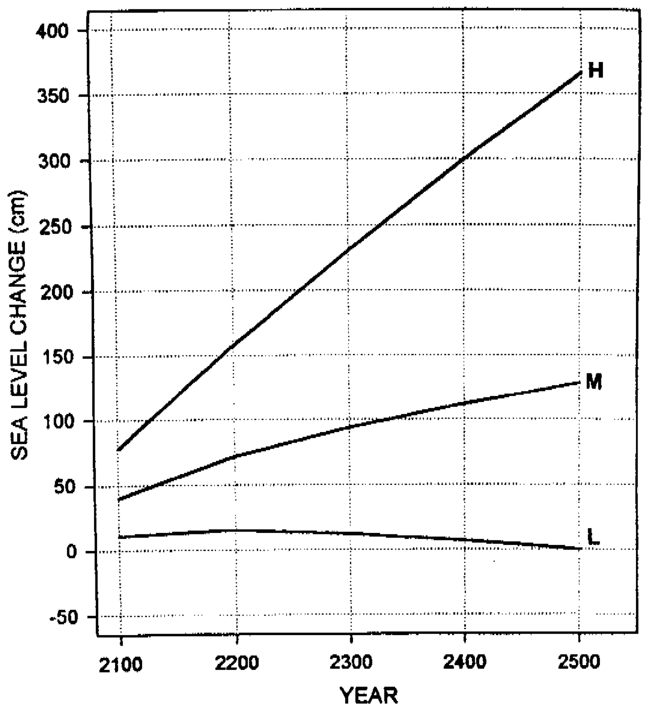


Figure 9.4 High (H), Medium (M) and Low (L) Sea Level Changes for the 750ppm Stabilisation Case. (From Pittock, 1993)



A trial definition of intergenerational equity is:

intergenerational equity involves the maintenance of an environment at least as healthy, productive and diverse as now. This involves the retention of the same, or a better, range of options as now, access to the same or better range of resources, quality of environment and amenities as are now available, and solutions to identifiable problems within one generation (thirty years) or, at least, reversal of the problem.

Young (1993a) notes that acceptance of intergenerational equity as an objective means that the present generation is required to ensure that the health, diversity and productivity of natural resources are maintained or enhanced for the benefit of future generations. Conceptually, if these considerations are accepted, then opportunity to exploit or derive income from Australia's resources is limited by an obligation to leave society as well endowed at the end of a period as it was at the beginning. This implies that society must conserve the value of its asset base and make sufficient investments to compensate for any depreciation or degradation that occurs during the period.

The concept of intergenerational equity, especially when applied to the issue of climate change, highlights the "never-ending debate" (Young, 1993 a,b) over the most appropriate discount rate to use to compare costs and benefits in different time periods. Young (1993a) points out that it is relatively easy to show that the most commonly recommended technique discriminates against future generations. Spash (1994) has done this by showing that almost any positive rate creates insignificant present values for even catastrophic losses in the further future. This problem has received widespread attention. Spash (1994) points out that, in the case of climate change, cost-benefit analysis is inconsistent with the concept of intergenerational equity because one will always be comparing present day costs with discounted future benefits, so that the costs of controlling greenhouse emissions will always exceed the benefits to future generations. An alternative view, expounded by Shlyakhter et al. (1995) is that the appropriate discount rate to use is the same rate as money. The argument, based on that of Raiffa et al. (1977), is that money can be invested now, at the monetary discount rate, to balance the risk over future generations so that by the time the hazard arrives the money has increased appropriately by means of the accumulated interest.

These inadequacies in traditional forms of economic analysis were recognised and given prominence in the US EPA report *Reducing Risk*. (US EPA, 1990). This report made ten recommendations, the last of which was: "EPA should develop improved methods to value natural resources and to account for long-term environmental effects in its economic analyses" because it was recognised that traditional forms of economic analysis systematically undervalue natural resources and the report specifically highlighted the discounting procedure as one of the limitations of the presently available tools of economic analysis.

Young (1993a) has carefully analysed the problems of conventional discount rate and cost-benefit methodologies and pointed out that there exist solutions to all the five problems that he lists. He advocates that the best interim strategy for decision making is to use a combination of techniques to ensure that projects pass the three 'E' tests:

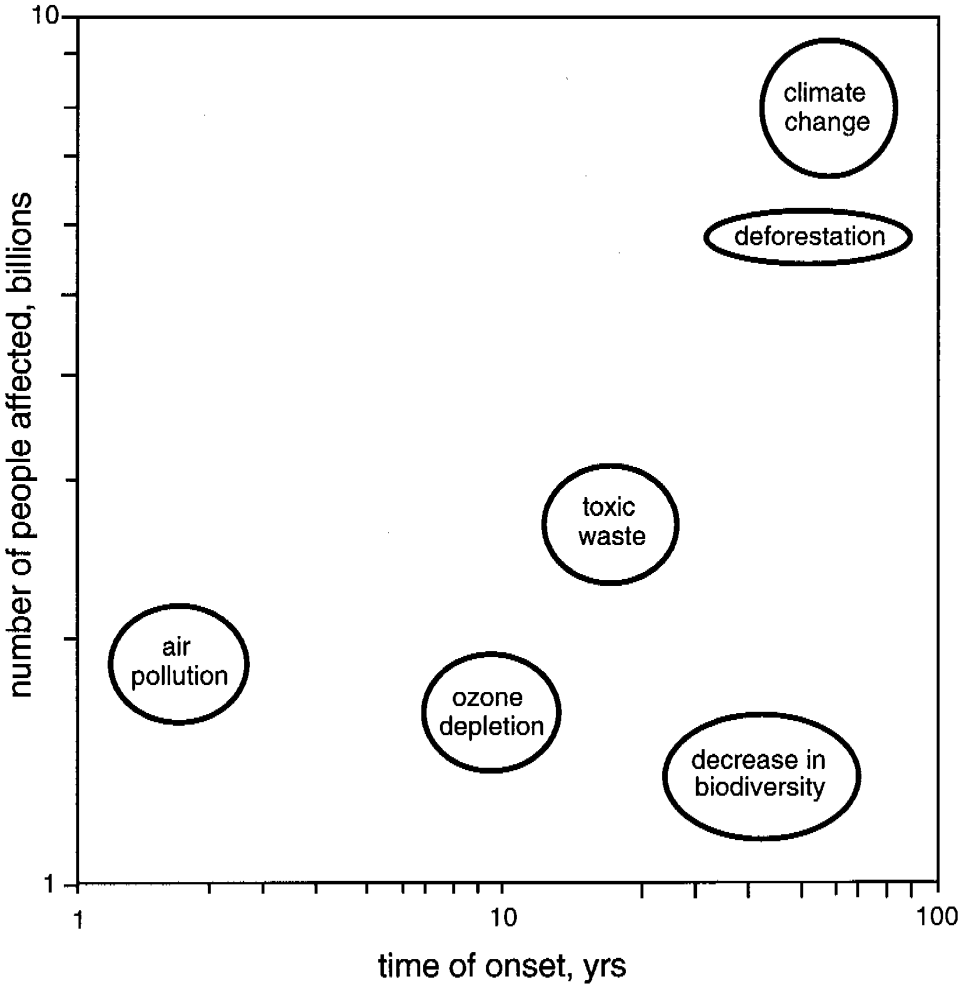
- economic efficiency;
- environmental integrity; and
- equity

Economic efficiency is assessable through conventional cost-benefit analysis. Environmental integrity can be tested by environmental impact assessment or by environmental risk assessment. Equity seeks to distribute the burden of the risk based on some weighting of individual welfare. The risk can be distributed evenly across the whole population or can be distributed based on some other parameter. The issue of appropriate intergenerational equity tests has not yet been determined.

Discussion

Figure 9.5 illustrates why climate change provides the best illustration of both the precautionary principle and intergenerational equity. The figure illustrates the relative ranking of hazards in terms of their potential impact as determined by the US EPA (1990). Climate change gives rise to the highest expected ecological impacts, but takes the longest time to do so.

Figure 9.5 Ranking of environmental risks (EPA 1987, 1990) (From Shlyakhter et al, 1995)



Returning to the aims of the case study, the first question was:

- What form of assessment of the risk-weighted consequences of climate change has been undertaken, as required under the precautionary principle?

Shlyakhter et al. (1995) undertook an integrated risk assessment of climate change. The term, integrated, in this context means that the economic, as well as the technical, aspects of climate change are considered. Even the authors concede that for a risk assessment to be adequate it must be integrated in this sense so that even though the word 'integrated' should be unnecessary, it has acquired this usage in the climate change literature (Dowlatabadi & Morgan, 1993). An important feature of risk management related to climate change noted by Shlyakhter et al. (1995) seems to be the feeling among people that we should take an insurance policy, which amounts to considering the upper limit of a probability distribution of impacts. This upper limit is, in many respects, ill-defined but can be quantified provided one distinguishes between scenarios that are believed possible and those that are rejected as improbable. Empirical evidence suggests that overconfidence in predictions of future developments results in long tails of the distribution and, therefore, in high probabilities of surprise.

The IPCC process is an ongoing risk assessment of the consequences of climate change. But the noteworthy aspect of it is that, for a problem of such global scale and long temporal duration, the appropriate assessment involves: international cooperation; the involvement of numerous scientists; technologists; environmentalists; economists; politicians; lawyers; and other groupings, and as a result takes time and costs money.

Yet there is no doubt that a quick assessment undertaken by a small focused group would fail to win the consensus support that concerted action requires; and fail to spread ownership of the consensus across a sufficiently wide cross-section of the community.

The second question was:

- Is the concept of intergenerational equity consistent with cost-benefit analysis?

We believe that traditional cost-benefit analysis is inconsistent with the concept of intergenerational equity. It seems impossible to obtain economic efficiency (via traditional cost-benefit analysis) in reducing the risk of climate change and, at the same time, maintain intergenerational equity. Young (1993a) notes that the standards derived from the use of conventional cost-benefit analysis will always be less stringent than those derived from most interpretations of the precautionary principle and from consideration of intergenerational equity concepts. In fact, the issue of traditional valuation mechanisms in economic analysis is the fourth principle of environmental policy under the IGAE. As recognised by the US EPA, any attempt to use risk-benefit analysis as a basis for determining national environmental priorities will have to find better ways of valuing the benefits when there is a time delay in the appearance of the benefits.

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