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# ECONOMICS, ECOLOGY AND THE ENVIRONMENT

**Working Paper No. 167**

**Core Issues in the Economics of Biodiversity Conservation**

**by**

**Clem Tisdell**

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**Clem Tisdell**[2]

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# Core Issues in the Economics of Biodiversity Conservation


## ABSTRACT

Critically reviews the following core issues in the economics of biodiversity conservation: reliance on the stated preferences of individuals as a guide to biodiversity conservation, the relevance of the phylogenetic similarity principle (and other attributes of organisms) for the survival of species; the implications of the Noah's ark problem for selecting features of biodiversity to be saved and the difficulties raised by criteria based on safe minimum populations of species or on minimum environmental standards; the extent to which the precautionary principle can be rationally used to support the conservation of biodiversity; the impact of market extensions and globalization, as well as market and other institutional failures, on biodiversity loss; the relationship between the rate of interest and biodiversity loss; and the implications of intergenerational equity for biodiversity conservation. The consequences of changes in biodiversity for sustainable development are given particular attention.



**Keywords:** biodiversity conservation; economic valuation; intergenerational equity; phylogenetic similarity principle; precautionary principle; sustainable development.

**JEL Codes:** Q5, Q51, Q56, Q57

# Core Issues in the Economics of Biodiversity Conservation

## 1. Introduction

How to determine what set of genetically diverse organisms should be conserved is one of the most challenging issues of our time. However, it needs to be analyzed as part of a broader problem. Given that collections of organisms (for example, species, subspecies and varieties of these) can be retained, added to and subtracted from (often as a result of human activities, including genetic engineering)[1, 2], the broader problem is to determine the optimal time-path that genetic diversity should follow given the controlled variables available to humankind. If this problem cannot be solved, (as is probable given the bounded rationality of human beings[3]) it may still be possible to avoid biodiversity paths that are demonstrably inferior to alternative paths given agreed criteria for choice of biodiversity. The presence of bounded rationality does not render it impossible to make any rational decisions but it limits the scope for optimization.

Important issues for biodiversity conservation (a term which should really be interpreted in the wider manner identified above) include the impact of human institutions, such as market systems, on biodiversity conservation and the consequences of human desires for the conservation of ecological alternatives. The following matters will be discussed in turn in this article: the valuation of biodiversity conservation, market and institutional failures particularly in relation to agricultural biodiversity, implications of the rate of interest for biodiversity conservation and issues raised by intergenerational equity. Given the restricted space available, only limited coverage of this topic is possible. The breadth of this subject can be gauged from a recent book edited by Kontoleon, Pascual and Swanson entitled *Biodiversity Economics: Principles, Methods and Applications*[4]. Although this book is 664 pages in length, it by no means exhausts the coverage of this subject.

## 2. The Valuation of Biodiversity

How to appropriately value biodiversity is a major problem. In particular, we need to consider how much weight should be given to citizens' sovereignty in valuing biodiversity. Traditionally, economists have placed a heavy weight on the preferences of individuals in determining social choices about resource alternatives. However, a number of considerations make this approach to determining a socially optimal path for biodiversity problematic. For example, social values alter with the passage of time and they both shape and are shaped by individual values. Passmore[5] shows how Western ethical attitudes to nature have changed and Myrdal[6] stressed the importance of circular causation in relation to the formation of social values. Furthermore, attitudes towards nature often differ between cultures and they also reflect variations in cosmological views. In addition, social values probably alter with changes in objective circumstances; for example, the view that humans have a duty to conserve all living things may have strengthened because biodiversity loss has increased and has become more apparent.

Even if it is accepted that the preferences of all citizens about biodiversity should count, the problem remains of how to derive an acceptable social ordering from these, as was illustrated by Arrow's Social Impossibility Theorem [7]. There are also many problems in eliciting individual preferences for the conservation of biodiversity, not least of which are the knowledge constraints that individuals have about alternative possible states of biodiversity. While one would like individuals to express their preferences in a situation in which they are fully informed, at best, they can only be partially informed because of their limited capacities for comprehending, storing and processing information [8, 9].

The supply of information to individuals about species or natural systems to be evaluated usually causes their stated preferences for supporting the survival or conservation of those species or systems to alter[10, 11]. In addition, sensual experiences can alter stated preferences for the conservation of a particular species[12]. But the stated preferences elicited from individuals are unlikely to remain constant. If the initial stimuli are not reinforced, their impact on valuation weakens so that for example, willingness to pay for the survival of a species (or accept compensation for its loss) falls, even though no material changes occur other than the passing of time[13].

A Heisenberg-like[13] effect creates difficulties for eliciting from individuals their valuation of species and similar natural things. This is an additional problem to many others that have been encountered in using stated preference methods for evaluating environmental and ecological possibilities[14]. These difficulties include substantial differences in the amounts which individuals are willing to pay for retention of ecological possibilities and the amount they are willing to accept for the loss of this same set of ecological possibilities[15, 16]. In cases where there is a substantial difference between these two measures of valuation, it is necessary to make a moral judgment about which is the most appropriate criterion.

The question also should be considered of whether a deontological approach to valuing ecological alternatives is preferable to a utilitarian-type approach[17]. These approaches are sometimes irreconcilable – for example, those with strong ecocentric values may refuse to accept social choices supported by those with strong anthropocentric utilitarian values. However, some individuals (probably most) may accept a combination of these values, for instance, man-centered utilitarian valuations may be accepted subject to the fulfillment of various 'moral imperatives' about the treatment of nature.

## 3. The Noah's Ark Problem

The Noah's Ark problem can be used to illustrate several important social choice issues in biodiversity conservation, especially if it is combined with the assumption that the ark has limited capacity and therefore, only some species can be saved and the remainder must perish. This problem focuses attention on the need to decide on the ecological alternative to be conserved and to determine the other alternatives that muse be forgone.

It has been contended by some social scientists[18, 19], that if human preferences are used to determine which species will be saved, preference will be given to saving species that show greater similarity in appearance to human beings than others or which have similar biological characteristics to humans. Thus, species of mammals are likely to be preferred to bird species, bird species are preferred to reptile species and so on. Tisdell *et al.*[20] found empirical support for the similarity principle based on whether or not a sample of respondents favored the survival of each species in a group of 24 Australian species of mammals, birds and reptiles. However, it was also found that amongst the set of reptiles, turtle species were so highly liked and supported for survival that the similarity principle was not fully satisfied. A dichotomy existed in the likeability of different reptile species and in public's support for their survival.

The above-mentioned type of research aims to determine how individuals evaluate different species based on the characteristics of the species. However, the humanoid similarity of species is not the only attribute influencing such evaluation. For example, Metrick and Weitzman[21, 22] found that the size of the adults of a species and their perceived danger to humans (visceral factors) are also influences on the likeability of species.

This raises the question once again of the extent to which individual preferences of this nature should be respected in social decision-making. Deontologists with an ecocentric bent would most likely not accept social decision-making based solely on individual preferences as a guide to biodiversity conservation because it fails to give due weight to moral imperatives such as humankind's duty to steward nature. In reality, mixed ethical systems seem to exist in many societies. For example, individual preferences may be respected in social decision-making provided that they do not conflict with basic moral principles encapsulated in social values.

Apart from this moral perspective, respect for individual preferences as a basis for decisions about biodiversity conservation needs to be tempered by the extent to which individuals are rational and well-informed about alternative ecological possibilities and their consequences.

Although formulations of the Noah's Ark problem are far from perfect in capturing the basic biodiversity choices facing humankind, they highlight the need for trade-offs in the survival of species (the likelihood that some can continue to exist but not others) or in sustaining other features of biodiversity. Many economic studies intended to estimate the contingent valuation of individual species or selected features of biodiversity fail to take adequate account of such trade-offs. Furthermore, it should be noted that willingness of individuals to contribute to or pay for the conservation of a particular species or a natural ecosystem usually differs from their willingness to support its survival[11]. This is because the willingness of individuals to contribute to the conservation of a species (or some other feature of the natural world) partly depends on the extent to which its existence is threatened. For example, Tisdell *et al.*[11] found strong support in Australia for the survival of the red kangaroo but a reluctance to contribute funds for its conservation, because it is abundant and not endangered.

An advantage of considering the constrained Noah's Ark problem is that it demonstrates the limitations of some suggested decision-making criteria for determining the conservation of biodiversity. In particular, Ciriacy-Wantrup's suggestion[23] that all species be conserved at a safe minimum population may be unable to be satisfied because the limited availability of resources makes this impossible[24]. Furthermore, Bishop's qualification[25] that this should be so for each species unless the cost of achieving it is unacceptably high for some, begs the question of what is 'unacceptably high'. Again, no completely safe minimum population may exist for any species[26].

If the net social value of all components of biodiversity can be expressed in monetary terms, then in principle, it would be possible to determine the ecological states that would maximize the net social value of biodiversity. Apart, however, from the question of whether an acceptable measure of this type could be obtained, the estimated values are bound to be uncertain. It is even doubtful whether acceptable probabilities could be assigned to the likely value of all components of biodiversity. But if this could be done, then in principle, the composition of biodiversity that maximizes expected net social benefit could be found. However, this would imply that a risk-neutral attitude be taken towards biodiversity conservation, and this is unlikely to be socially acceptable.

## 4. Uncertainty, the Precautionary Principle and Decisions about Biodiversity Conservation

It is widely accepted that the benefits of conserving individual species and components of biological systems are uncertain. It is usually contended that in these circumstances, it is wise to be cautious in decision-making and that it is likely to be rational to err in favour of conserving biodiversity. This has been dubbed the precautionary principle. However, this matter is much more complicated than seems to be the case at first sight. For example, a high preference for security can favor development and loss of species or ecosystems because the benefits from development can be more certain than those from the conservation of particular species and ecosystems[27]. This is partly a reflection of the adage that 'a bird in the hand is worth two in the bush'. The optimal choice does, however, depend on the particular structure of the decision problem.

It has been pointed out that when risk neutrality exists, it may be rational to err in favor of the conservation of species or other components of ecological systems if there is uncertainty about the benefits to be had by their conservation[28, 29]. However, even when risk neutrality exist, whether this precaution is rational depends on the structure of the possible outcome.

Suppose that the benefits from conserving a species (or some of the components of an ecological system) are uncertain but depend on the magnitude of a property (or attribute) of it that is yet to be measured. Assume that while the magnitude of this property is uncertain now after a specified period of time, it will become certain. Let $x$ measure the magnitude of this property and let $y$ be the benefit from it. Assume that the benefit, $y$, is a function of $x$ such that:

$$y = f(x) \text{ and } f'(x) > 0. \qquad (1)$$

Now, as can be deduced from Theorem 90 of Hardy *et al.*[30], if $f(x)$ is strictly convex (for example, if $f'' > 0$) then the expected value of $y$ will tend to rise as the value of $x$ becomes more uncertain, that is, as its probability distribution becomes more dispersed. If probabilities can be assigned to the probable values of $x$ and its value is uncertain, then

$$f(\mathrm{E}[x]) < \mathrm{E}\,[f(x)] \qquad (2)$$

In other words, the uncertainty of benefits from conserving the species raises its expected benefit compared to a situation in which its benefit is certainly $\mathrm{E}[x]$. On the other hand, if the benefit function $f(x)$ is strictly concave, (for example, $f''(x) < 0$) the opposite is the case – uncertainty does not favor the conservation of the species. In the linear case, uncertainty does not alter the expected benefit from conserving a species. Note that using the certainty equivalent $\mathrm{E}[x]$ will undervalue the expected benefit of conserving the species if $f(x)$ is strictly convex and it will overvalue its expected value if $f(x)$ is concave. Thus, as discussed by Theil[31], the use of certainty equivalents in optimization problems can result in sub-optimal decisions.

The simple example shown in Figure 1 illustrates these relationships. There the curve marked ABC represents a strictly convex situation and curve GH represents a strictly concave relationship. Suppose that the property (attributes) preserved by the species (or other component of biodiversity) will either turn out to be $x_1$ or $x_3$ with a probability of 0.5 each. Then $\mathrm{E}[x] = x_2$, the mid-point between $x_1$ and $x_2$. In the convex case, there is a 0.5 probability of $y$ having a value corresponding to point A or to point C. Therefore, the expected value of $y$ is $y_2$ (the value corresponding to the mid-point of the chord connecting points A and C) and is in excess of that at point B, namely $y_1$, which would be its value if $x$ were equal to $\mathrm{E}[x] = x_2$, in which case uncertainty would be absent. Similarly, in the concave case depicted by curve FGH and making similar assumptions to those in the previous uncertainty cases, the expected value of the benefit function to be less than its value when $x = \mathrm{E}[x]$. In this case, the expected value of the benefit function is $y_4$, corresponding to point G, if uncertainty prevails but is only equal to $y_3$, corresponding to point J, if $x = \mathrm{E}[x]$. Whereas in the convex case, uncertainty favors precaution and conservation of a focal species (or another component of biodiversity), the opposite is so in the concave case. The linear case exhibits neutrality in that regard.

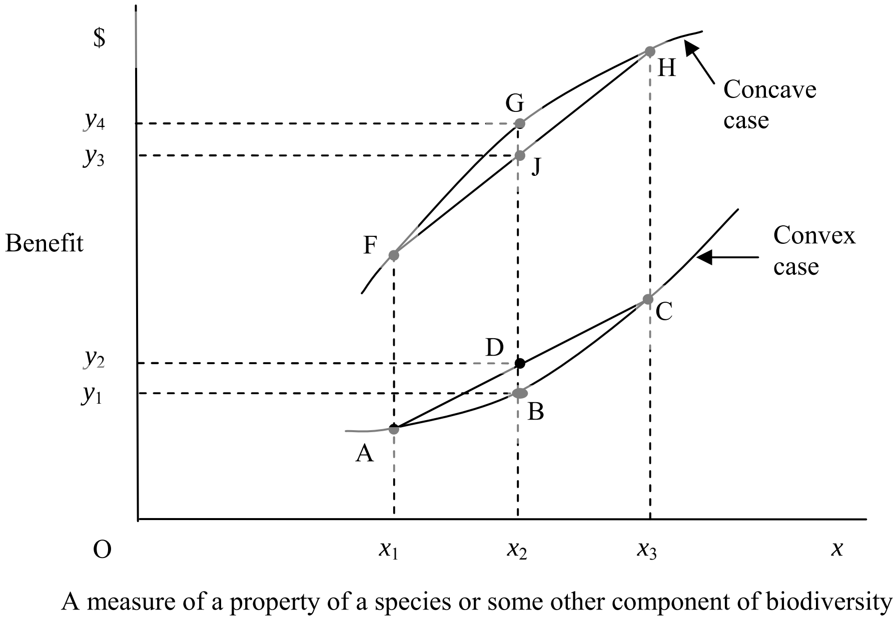


**Figure 1.** A simple illustration of situations in which uncertainty about the value of a species (or some other component of biodiversity) favors its conservation in one case but not in another case. Uncertainty does not always favor the conservation of biodiversity even when there is no risk aversion.

While the above discussion indicates that the precautionary principle cannot always be rationally invoked as an argument in favor of biodiversity conservation, it ignores the significance of the intergenerational benefits from biodiversity conservation and problems involved in interpersonal comparisons of benefits. Intergenerational equity considerations are likely to provide support for biodiversity conservation. This will be discussed later.

## 5. Market and other Institutional Failures, Market Extensions, Changed Production Methods and Globalization.

Market failures and other institutional failures, the extension of markets, changed production methods and globalization have all contributed to biodiversity loss. Much has been written about how markets may fail to minimize economic scarcity and add to biodiversity loss and also about similar losses caused by political and administrative failures. Factors such as environmental externalities, public good attributes of ecological systems, uncertainties and shortcomings in property rights regimes are typically given considerable attention in relation to market failures[32]. Much less attention seems to have been given to the extension of markets, changes in production methods and increased globalization as forces contributing to biodiversity loss. These factors are, however, major contributors to loss of agricultural biodiversity, and similar types of losses occur in relation to forests and aquatic systems. The mechanisms involved are varied.

The extension of markets (of which growing economic globalization is one manifestation) usually results in greater specialization in economic production as predicted by the law of comparative economic advantage[33, 34]. This may result in industries or activities reliant on unique local genetic material disappearing and the subsequent loss of the genetic material itself. For example, in Ghana as a result of international economic activity, the growing of tree crops, such as cocoa, has developed displacing a local breed of cattle. Market extension has also resulted In many local varieties of crops and breeds of livestock being replaced by exotic or improved varieties or breeds. This process is facilitated by technological and trade developments that tend to reduce the extent to which the production of bio-industries are tied to locally available resources. For example, Vietnam's local breeds of pigs have been replaced, to a large extent, by exotic strains of pigs. The productivity of the improved pig varieties depends on improved husbandry and food with a high nutritional value. Much of the food is imported. Consequently, pig production is increasingly decoupled from local environmental and resource conditions. Modifications of local conditions increases the extent of global uniformity in the environmental and resource possibilities faced by bio-industries and results in greater uniformity of utilized genetic material. Genetic material well adapted to natural local conditions is lost. Human management (facilitated by international trade in agricultural inputs) tends to result in increased uniformity in the constructed niches in which biologically based production occurs. Consequently, less genetic diversity is needed for bio-production than otherwise. However, this loss of genetic diversity is not without potential economic costs because it reduces future genetic options that is, flexibility in decision-making.

There are, of course, many factors that influence the extent of agricultural biodiversity loss as has been pointed out by Smale and Drucker[35] in reviewing relevant economic literature. However, many of the findings in the literature are consistent with the view that, on the whole, agricultural biodiversity is reduced by market extension (greater access of farmers to markets) and by changes (such as technological changes) which reduce the heterogeneity of environmental conditions under which crops grow or in which livestock are husbanded. This increased environmental homogeneity is due to human manipulation of agro-environments.

It is also clear that in cases where market extension leads to increased demand for an open-access resource (or one for which property-rights regimes are imperfect) that other things constant, this will tend to lead to a more rapid depletion of the resource. In the case of a living resource, the likelihood of it being extinguished increases. The provision of roads and similar infrastructure in remote regions accelerates deforestation and consequently, biodiversity loss by increasing market access[36]. However, as pointed out above, such loss may occur even if market failures are absent. Nevertheless, when market failures occur in biodiversity conservation, market extension (including increased globalization) can be expected to accelerate biodiversity loss as suggested by Alam and Van Quyen[37].

Another feature of increased globalization is that it has increased the rate and extent of spread of genetic material between regions because humans have increasingly facilitated this spread. This spread has sometimes been deliberate and at other times accidental. Some of the issues involved are discussed by Perrings[38]. Often it has had negative spillovers and it has been a force making for the reduction of biodiversity globally. For example, the introduction of livestock to Australia by European settlers has been implicated in the disappearance of some Australian indigenous species. The introduction of the cane toad to northern Queensland to control a beetle pest in sugar cane has turned out to be a biological disaster because it has spread (and continues to do so) and poses a threat to the survival of several Australian native species.

## 6. The Rate of Interest and Biodiversity Conservation

In the economics literature, an increased rate of interest is usually seen as a deterrent to the conservation of economic resources. Two main reasons are usually advanced: (1) it reduces the discounted present value of benefits to be obtained from delaying the use of the resource, other things constant and (2) it increases the likelihood that those owning such resources can increase their returns by realizing the current value of the asset and gain by investing the funds in the capital market. Furthermore, intergenerational equity suggests that a zero discount of realizable benefits between generations would be socially appropriate, as is argued in *The Economics of Ecosystems and Biodiversity: Interim Report*[32] and by Ramsey[39]. It is instructive to examine these matters closely.

Consider the view that a high rate of interest is inimical to biodiversity conservation[40]. Whether or not this is so depends on the particular circumstances. If the steady-state economic return from the stock of a unique organism is constant, then once the rate of interest rises above this constant level, the incentive to realize the value of the stock of the organism tends to increase. This is so if it is assumed that the cost of liquidating (realizing) the living asset is constant and that its total realizable value is constant. The lower is the cost of harvesting the stock of the organism, the more likely is the stock to be extinguished as the rate of interest rises, other things held constant. As the rate of interest rises, it becomes more profitable to realize the capital value of the standing stock of the unique organism and invest the funds obtained at the going rate of interest.

Another mechanism leading to the extinction of unique organisms in a commercial setting is their replacement by organisms that give a higher economic return. For example, slow growing and less valuable tree species may be replaced by faster growing and more valuable ones. In practice, the replacement species are often exotic to the region where they are grown. However, the replacement of the species is not without initial costs. Costs can be expected to be incurred in the replacement period and income can be expected to be forgone during the gestation period before the replacement crop (species) becomes commercially productive. These costs create an economic disincentive to switch to the replacement species. Furthermore, the replacement disincentive magnifies as the rate of interest rises, other things being held constant.

This can be illustrated by a **simplified** case. In Figure 2, line ABCD represents the net income flow from utilizing a unique species, other things being held constant.

Suppose that at time $t_1$ it becomes apparent that this species could be replaced by another giving a higher net income flow after the replacement species is established. However, initial costs must be incurred to achieve the adjustment and consequently, if the replacement is undertaken at $t_1$, the net income path is assumed to become EFGH, where $t_3$ is assumed to be the time horizon for this decision problem, If the rate of interest is zero (and no discounting occurs), it is profitable to switch to the new species if the area of rectangle GCDH exceeds that of BEFC and not to do this if the opposite relationship prevails. If both these areas are equal, then either of the alternative strategies is equally profitable. However, if in this case, a positive interest rate prevails, replacement of the existing species is no longer profitable because the discounted value of the income flow in the area of rectangle GCDH will be less than that in the area of rectangle BEFC. In general, a higher rate of interest will be a deterrent to the replacement of the existing species by another in a situation like this. Therefore, in cases like this, a higher rate of interest is a deterrent to biodiversity loss, unlike in the previous case. Note also that the longer is the gestation period, $t_2 - t_1$, and greater is the reduction in income in this period, the lower is the economic incentive to replace the existing species by the substitute species.

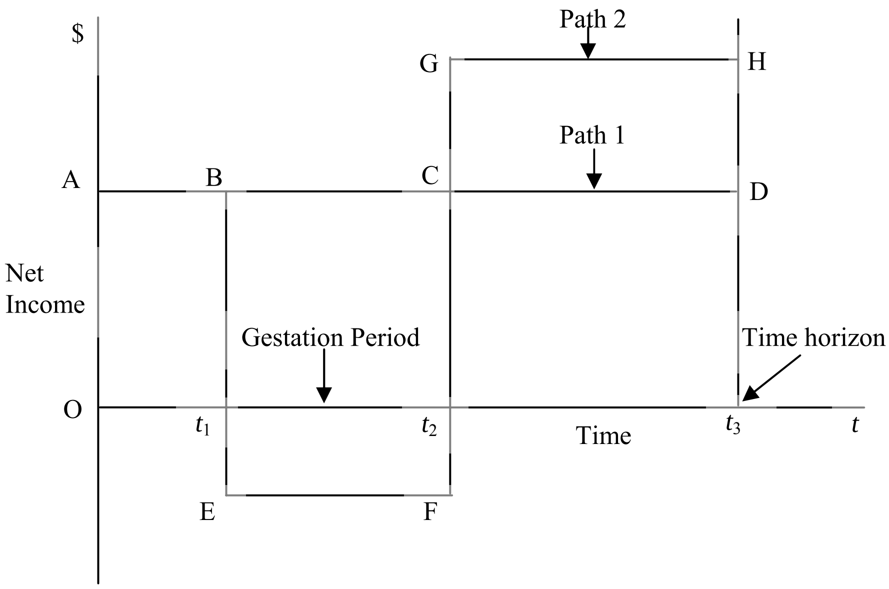


**Figure 2** An illustration of a case in which a higher rate of interest reduces the likelihood of the loss of a commercially utilized species as a consequence of its being replaced by another species.

The above theory is based on partial microeconomic analysis. Consideration of macroeconomic analysis also confirms that there is no simple regular relationship between the rate of interest and the likely extent of biodiversity loss[41]. Investment in man-made capital usually involves the transformation or depletion of natural capital and is a major source of biodiversity loss. Depending on the macroeconomic circumstances, the level of investment in man-made capital can increase or decrease when the rate of interest rises[41]. For example, suppose that in the neoclassical case illustrated in Figure 3 the demand for funds for investment is initially as shown by the line $D_1D_1$ and the supply of these are as indicated by $S_1S_1$. Market equilibrium occurs at $E_1$ with the rate of interest being $r_1$. The level of investment is equal to $X_1$. If the supply curve of savings (loanable funds) shifts up to $S_2S_2$ and the demand for investible funds remains unchanged, market equilibrium alters from $E_1$ to $E_2$. The rate of interest increases from $r_1$ to $r_2$ and the level of investment declines from $X_1$ to $X_0$. Given that the level of investment is positively associated with the rate of biodiversity loss, the rate of biodiversity loss declines. On the other hand, if the supply curve of loanable funds remains unaltered and the demand curve for the funds shifts upwards, the rate of interest rises and so does the level of investment. For example if the demand curve shifts up to $D_2D_2$ market equilibrium alters from $E_1$to $E_2$, the rate of interest goes up to $r_2$ and investment increases from $X_1$ to $X_2$. Thus, if increased investment in man-made capital poses a heightened threat to biodiversity conservation, biodiversity loss tends to rise. Therefore, one cannot judge just from the sign of variation in the rate of interest whether there is an increase or decrease in biodiversity loss. Similar results hold for IS-LM models.

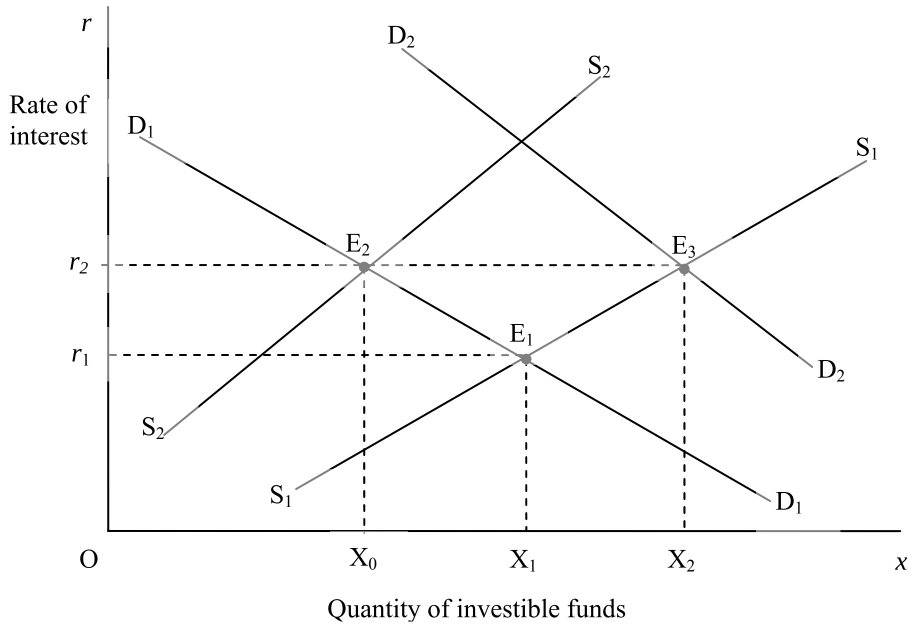


**Figure 3.** In a microeconomic setting, a rise in the rate of interest may be accompanied by either a rise or fall in the level of investment, as is illustrated above. Consequently, if biodiversity loss is positively associated with the level of investment, a rise in the rate of interest can be associated with an increase or with a fall in the rate of biodiversity loss, and vice versa.

In IS-LM models, a rise in the rate of interest can be associated with a rise or a fall in the level of investment and GDP and the same is true of a fall in the rate of interest. For example, if the LM curve shifts to the left with IS curve unchanged, the rate of interest rises and the levels of investment and of GDP fall. Should the IS curve move to the right with the LM curve unchanged, once again the rate of interest rises but this time, the level of investment and of GDP go up. Similarly, a decrease in the rate of interest may be associated with a decline in the levels of investment and of GDP or with an increase in these depending on how the change is generated. Thus, if in a macroeconomic setting, increases in investment and GDP are associated with a higher rate of biodiversity loss (as is likely), there is no regular association between changes in the rate of interest and the rate of biodiversity loss.

There is evidence from the economic literature on behavioral economics that individuals do not use a constant rate of discount to estimate the present value of future benefits but use a discount rate that declines in a hyperbolic fashion as a function of time[42]. This means that their present values of distant benefits and costs are higher than estimated by the traditional economic method of discounting. Whether that will favor greater biodiversity conservation is unclear, but it may do so. However, the reasons for hyperbolic discounting by individuals needs more investigation in order to determine whether it would be socially rational to adopt a similar procedure for social discounting. We must face the possibility that some observed behaviors are not rational even though they occur frequently.

## 7. Intergenerational Equity and Biodiversity Conservation

The desirability, or otherwise, of conserving biodiversity has become an integral part of the debate about the necessary requirements for achieving sustainable development. While human actions reducing biodiversity now may benefit current generations (or nearby generations), they may disbenefit generations further into the future. In fact, future generations could be impoverished by such actions. Nevertheless, the relationship between current biodiversity loss and the welfare of future generations remains extremely uncertain and there is lack of agreement on the ethical principles that should be adopted to choose between the alternative possible paths of human well-being that could prevail. One view about a desirable path of sustainable development is that it be such that the welfare of each generation be not less than that of its predecessor. However, that is not a requirement of Rawls' principle of justice which is often used to provide an ethical underpinning to the desirability of sustainable development[43]. Rawls claims that equality of income (well-being) of individuals is desirable **unless** inequality is to the benefit of all. Theoretically, it is possible that some types of biodiversity loss (or change) could result in all generations being better off than without such loss (change) but result in some future generations being less well off than their predecessors. For example, the alternative pathways shown in Figure 4 may apply if $t_n$ is assumed to be the end of the time-horizon. Let pathway ABC represent the well-being of successive generations in the absence of biodiversity loss and let path ADE be that with some biodiversity loss or change induced by human actions. If Rawls' principle is adopted, path ADE is the most desirable alternative because it results in the well-being of every generation being greater than for the alternative path, ABC. This is so even though after $t_1$, each successive generation has a lower level of well-being than its predecessor.

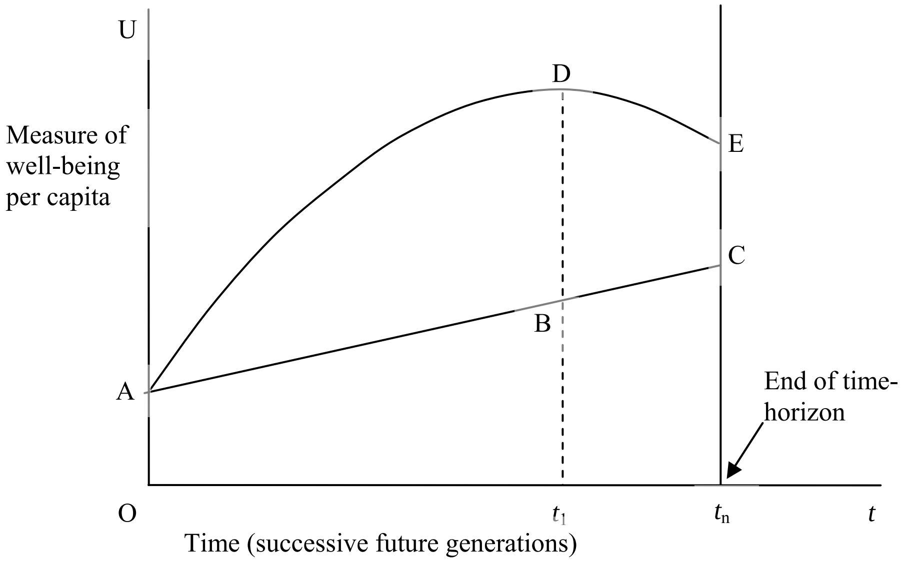


**Figure 4.** An illustration of the possibility that some biodiversity loss (change) could result in a higher level of well-being for all generations compared to no biodiversity loss. This is so, despite the welfare of some future generations declining compared to that of their predecessors if some biodiversity loss occurs.

It is also conceivable that some biodiversity loss (or change) could result in the welfare of some future generations falling below that which could prevail in the absence of biodiversity loss or if there is only a slight loss in biodiversity. For example, the situation illustrated in Figure 5 is possible. There the path ABC represents the path of well-being in the absence of biodiversity loss and curve ADEF indicates that when some biodiversity loss or change occurs. In this case, generations coming after $t_2$ are worse off when some biodiversity loss or change occurs compared to a situation in which there is no biodiversity loss. Therefore, if Rawls' principle of justice is adopted, the path with no biodiversity loss would be preferred to that with some biodiversity loss or change. However, it still may be that alternative normative criteria to that of Rawls results in path ADEF being chosen as socially superior to ABC.

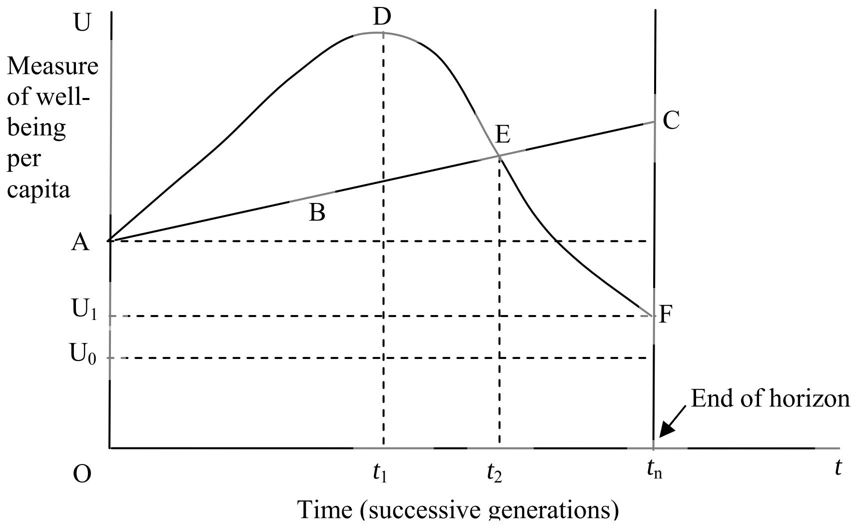


**Figure 5.** Illustration of a case in which the option of biodiversity loss (or change) does not satisfy Rawls' principle of justice but is socially superior for an alternative social norm based on a safety-first principle.

For example, if all individuals could consult prior to their being born and assuming similar conditions to Rawls[43], they might agree to the adoption of a development path that maximizes their expected well-being subject to their well-being not falling below an acceptable level[44]. If the acceptable minimum level of well-being for any generation is $U_0$, the development path ADEF corresponding to some biodiversity loss or change might satisfy this safety-first rule, as was discussed by Tisdell[45].

In the hypothetical situation envisaged by Rawls[43] , the optimal development path depends on how yet-to-be-born individuals estimate their probability of being born into each possible future generation or of being born at any future point in time. One possibility is that they could adopt Laplace's rule of insufficient reason, namely that in the case of completely uncertain events, each possible event should be assumed to be equally probable. On this basis, the yet to be born may assume that the probability of their being born into any future generation (or at any future point in time) is equal for each. In that case, the expected value of the path ADEF to the yet-to-be-born would exceed that of path ABC because, from inspection, it can be seen that the area of the set bounded by ABED exceeds that of the set bounded by EFC. Therefore, path ADEF, which hypothetically involves some biodiversity loss (or change) is socially superior to path ABC, which hypothetically involves no biodiversity loss or a minimal change in biodiversity. This is so because it maximizes the expected well-being of future generations and at the same time, ensures that the well-being of no generation falls below an acceptable standard.

But given the same conditions, if the acceptable level of well-being for every generation exceeds $U_1$ but is less than AO, it does not. In that case, the path ABC, which hypothetically occurs if there is no biodiversity loss, is superior.

Although it does not negate the conclusions drawn above, it should be kept in mind that the estimation of probabilities based on Laplace's principle of insufficient reason is sensitive to the way in which possible events are envisaged. For example, the yet-to-be-born may assume that their probability of being born into a future generation is equal to the proportion of the future population to be born into that generation. Therefore, in this case the expected values of the development paths are sensitive to distribution (over time) of the future population. However, in the longer term, the levels of future human population are extremely uncertain.

Despite the limitations of the above model, it does raise some important policy issues. For example, *The Economics of Ecosystems and Biodiversity Interim Report*[32] is inconclusive in its recommendations about whether the economic benefits received by future generations should be discounted when valuing alternative paths of future economic benefit. Nevertheless, on equity grounds, this report appears to favor a zero discount rate and even suggests that a negative discount rate might be justifiable (see pages 30-31). However, neither is satisfactory because the sum of future benefit or well-being values of all who will live, discounted or not, is not a satisfactory indicator of the optimality or otherwise of alternative benefit paths. The nature of the paths themselves needs to be compared. For example, the intergenerational path ADEF in Figure 5 gives a higher value than path ABC when a zero discount rate is applied. However, if the minimum acceptable level of benefit (well-being) for any future generation must exceed $U_1$ (for example, is OA), then path ABC is preferable to path ADEF even though its present undiscounted value is less than that for ADEF. This could still be the case if a small enough negative rate of discount were applied. This matter was raised by Tisdell[27] in relation to the introduction of genetically modified organisms.

The above development models assume perfect knowledge of changes in biodiversity and the well-being of humans. Even in these cases, social choice is complicated. Uncertainty about these variables adds to this complexity. For example, the development and use of genetically modified organisms (GMOs) can alter biodiversity in uncertain ways. Furthermore, the development of a GMO or a new organism by humans may lead to an expanding but uncertain range of subsequent development of organisms by humans, thereby further adding to uncertainty about future states of biodiversity. Technological optimists are liable to see these developments as a way of continually raising human well-being whereas technological pessimists are afraid they will end in biological and economic disaster. Irreducible risks and uncertainties exist about the consequences of human manipulation of biodiversity. This seems to be an inescapable source of social conflict because attitudes of individuals to the bearing of risk and uncertainty vary considerably.

## 8. Conclusion

Several core issues of relevance for social decision-making about biodiversity conservation have been outlined. While these issues are substantive, they are not exhaustive. Reliance on individual human preferences to determine alternative biodiversity choices was shown to have several limitations. For instance, social conditioning and knowledge variations influence the attitudes of individuals towards the conservation of different organisms and components of biodiversity. While it would be comforting to believe that evolution of social values results in more enlightened individual preferences and values, we cannot be sure that this is always historically the case. There also appear to be ‘biases’ in human preferences for the survival of species as indicated for example by the similarity principle. Furthermore, human preferences are sensitive to the provision of information which given the bounded rationality of individuals, has to be selective.

The presence of uncertainty creates major problems for the evaluation of choices about biodiversity conservation. Consequently, it has been suggested that it is rational to adopt a precautionary approach to biodiversity loss. However, conservation of biodiversity is not always favored by a precautionary approach to decision-making.

As is well known, market failures of various kinds can contribute to biodiversity loss. However, it also appears to be the case that the extension of markets and globalization generate processes that play major roles in hastening biodiversity loss, even in the absence of market failures. Some of the mechanisms that cause this to happen have been identified. Furthermore, the structure of economic systems globally make it very difficult to moderate economic growth that erodes the stock of biodiversity[46]

Some economic literature suggests that rises in the rate of interest are likely to hasten biodiversity loss. While this can happen in particular circumstances, it is by no means always true. There is no simple relationship between changes in the level of interest and the rate of biodiversity loss, as evidenced both by microeconomic and macroeconomic analysis.

Loss of existing biodiversity tends to reduce the natural capital of society, for example, the loss of genetic material in the wild. In the case of biodiversity loss in domesticated livestock and cultivated crops, human-created capital is reduced. Both these sources of biodiversity loss can threaten sustainable development. Some such losses may benefit existing generations but be a disbenefit to future generations. As was illustrated, difficult intergenerational equity choices can emerge as a result of this. These are compounded by uncertainty about development paths that may emerge from alterations in biodiversity. For example, the impact of the development and use of GMOs on existing biodiversity is often uncertain and so are the long-run consequences of these developments. For example, the development of one GMO may expand options for developing others but these developments may be fairly unpredictable and its impact on other species may remain uncertain. While optimists are likely to have a very favorable view of likely outcomes, pessimists (realists?) worry about the possible results and their consequences for biodiversity and human welfare.

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