# Generational Cost Benefit Analysis for Evaluating Marine Ecosystem Restoration

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## Abstract

Conventional Cost Benefit Analysis (CBA) tends to show that most ecosystem restoration programs are not worthwhile in economic terms. This is because discounting significantly reduces future net benefits from restoration, since benefits are discounted using the time perspective (i.e., the discounting clock) of the current generation only. I propose the use of what is termed Generational CBA, which discounts net benefits from the perspective of all generations. This CBA takes into account the fact that current restoration efforts may produce benefits to future generations, and that these benefits need to be valued using the respective discounting clocks of the generation receiving the benefits.

## Introduction

This paper introduces the concept of Generational Cost Benefit Analysis (CBA) for assessing the potential net economic benefits from marine ecosystem restoration. This is a CBA framework that takes into account the full benefits of ecosystem restoration to both the current and future generations. Restoration efforts are generally about something in the 'past' that has been lost and therefore is not available in the 'present'. Further, what has been lost is usually missed very much, and thus one would want to restore it not only for the 'present' but also the 'future'. Several articles have appeared recently in the literature highlighting the current sorry state of the world's marine ecosystems and the marine life they support (e.g., Safina, 1995, Pauly et al., 1998 and Pitcher, 2000, Jackson et al., 2001), and the need to undertake restoration efforts (e.g., Pitcher and Pauly, 1998). The FAO and the National Research Council (U.S.) maintain that sustainable harvests of world capture fisheries are approaching the ceilings imposed by nature (FAO, 1999; NRC, 1999). The FAO also reports that 70 per cent of world fishery resources are either fully, or overexploited (FAO, 1999). Overexploitation in the past means that many capture fishery resources are now producing below their full potential. The Magnuson-Stevens Fisheries Conservation and Management Act of the USA recognizes that many fish stocks in the U.S. are overfished, and therefore specifically calls for the restoration of depleted fish stocks in U.S. waters (Anon., 1996).

A number of marine restoration efforts are currently in place in many parts of the world. For instance, the U.S. House of Representatives recently approved $600 million to restore Pacific salmon. In arguing for these funds to be approved, the U.S. Congressman who sponsored the bill stated the following, "If we restore salmon populations, future generations – like their ancestors – can enjoy and prosper" (see the June 14, 2001 issue of *WorldCatch News Network*: www.worldcatch.com). This quote shows that future generations feature strongly when people argue for the restoration of marine ecosystems. The European Union and Norway have just announced a joint program for the restoration of cod stocks in the North Sea (see http://odin.dep.no/fid/engelsk/p10001957/pressem/008041-070046/index-dok000-b-n-a.html). After independence in 1990, Namibians decided to approve very low total allowable catches for their valuable hake fisheries, with the hope of restoring the once abundant hake biomass (see Sumaila and Vasconcellos, 2000). The United Nations and a number of South-east Asian countries have recently announced a restoration plan for the South China Sea. It is the view of this article that this trend will continue into the future, and hence an economic valuation technique that captures the benefits to current as well as future generations is needed.

First, I present the 'Back to the Future' approach for the restoration of marine ecosystems described in Pitcher (2000) that is relevant to this paper. Second, a description of the key elements of the Conventional Cost Benefit Analysis framework is given. Third, the article discusses the Generational CBA approach to evaluating ecosystem restoration benefits. Fourth, I make a comparison of the outcomes from the two approaches using an example based on a restoration program for a generic marine ecosystem. Finally, a discussion of possible areas for the extension of the ideas developed in this article is given.

## The 'Back to the Future' approach

The 'Back to the Future' Approach provides analytical tools for policy decision making with regards to ecosystem restoration programs (see Pitcher 2000). It consists of :

1. Model construction of 'past' and 'present-day' marine ecosystems;
2. Simulation of the present-day ecosystem under a status quo regime in which the current fishing pattern is retained;
3. Simulation of the present-day ecosystem under a well-defined regime of restoration, which is meant

to return the ecosystem to 'some' state in the 'past';
4. Computing the economic gains under (ii) and (iii).

## Ecological Modelling of Past and Present Ecosystems

The Ecopath and Ecosim modeling frameworks are used to implement steps (i), (ii) and (iii) while economic valuation techniques are used to implement step (iv). Ecopath is a static mass-balance model that describes the trophic relationships in an ecosystem (Christensen 1995). Ecosim is a dynamic version of Ecopath, which tracks ecosystem changes over time (Walters et al., 1997). Ecosim relies on a system of differential equations for each component i defined by

$$\frac{dB_i}{dt} = g_i \sum_{j=1}^{n} C_{j,i}(B_i, B_j) + I_i - MB_i - F_i B_i - \sum_{j=1}^{n} c_{ij}(B_i B_j) \tag{1}$$

where $B_i$ is the biomass of group i; $dB_i/dt$ is the rate of change in biomass; $g_i$ is the growth efficiency; $C_{j,i}$ is the food intake of prey j by group i; $I_i$ is the net immigration rate; M is the natural mortality from causes other than predation; $F_i$ is the fishing mortality and $c_{ij}(B_i.B_j)$ is the function used to predict consumption rates from $B_i$ to predators, $B_j$. By making $dB_i/dt = 0$ in equation (1), the dynamic system of equations (Ecosim) is reduced to its static version (Ecopath: see Christensen, 1995).

## Conventional Cost Benefit Analysis

Cost Benefit Analysis (CBA) is a conceptual framework for the evaluation of the economic desirability of a project, including ecosystem restoration efforts. The framework attempts to quantify and value the costs and benefits accruing from a project at different points in time, into a common unit – the Net Present Value (NPV). In general, the CBA technique consists of the following steps (see Angelsen and Sumaila, 1996):

1. Defining the alternatives (projects);
2. Identification of the major environmental effects;
3. Quantification in physical terms of the environmental effects;
4. Valuation of the costs and benefits;
   a. Between different income groups (intra-temporal);
   b. In time (inter-temporal): discounting;
5. Sensitivity and risk analysis;
6. Modifications of the project(s) and policy recommendations to meet stated objectives.

In terms of restoration projects, step (1) can be interpreted as defining alternative restoration goals. In other words, answering the question: How much of the 'past' marine ecosystem can and should society aim to restore?

Formally, the Conventional CBA can be expressed as:

$$NPV = \sum_{t=0}^{T} \frac{V_t - C_t}{(1+\delta)^t}, t = 0,1,2,.., T \tag{2}$$

where $V_t$ and $C_t$ are the gross benefits and total costs, respectively, from the project at time *t*, and $\delta$ is the discount rate. Equation (2) takes inputs from steps (1) – (4) above. A project is accepted if NPV>0, otherwise it is rejected. When used to decide between alternative projects, the project with the highest positive NPV is preferred.

This article addresses the question whether the CBA approach as outlined above is appropriate for the evaluation of marine ecosystem restoration projects. This question is relevant because most restoration efforts are bound to be long term projects that would result in huge costs in the short term/near future but could lead to significant benefits in the distant future. Discounting has been identified in the environmental economics literature as a possible source of problems for the CBA technique when dealing with projects with long-term benefits but short-term costs. Some economists, notably those dealing with issues with long-term consequences such as the impacts of the actions of the current generation on climatic change, have questioned the prevailing levels of discount rates. Some have argued that rates currently in use are too high and therefore should be lowered (see Nordhaus, 1997). Others have proposed the use of different and lower rates when analyzing problems with long-range consequences such as climatic change (Hasselmann et al., 1997).

However, most economists, including Nordhaus (1997) caution against tampering with the discount rate – they argue that lowering the discount rate could serve as a double-edged sword with respect to conservation, because resource intensive projects that would otherwise not be profitable from the perspective of private investors could turn out to be profitable with a lower discount rate. The proposal presented here does not suffer this problem because it does not tamper with the discount rate to apply as seen from the perspective of the generation in existence – rather, it applies the same discount rate using different discounting clocks for each generation.

Weitzman (1998, 2001) states that a critical feature of the distant future is currently the unresolved uncertainty about what would then be the

**Table 1:** Groups of marine creatures, prices and fleet types used in the hypothetical example.

| No. | Group name | Prices (US$/t) | Fishing Fleet |
|---|---|---|---|
| 1 | Toothed whales | 270 | Foreign Pelagic |
| 2 | Baleen whales | 909 | Foreign Demersal |
| 3 | Pinnipeds | 114 | Line + Gill |
| 4 | Seabirds | 1,471 | Danish Seine |
| 5 | Adult Cod | 1,080 | Bottom Trawl |
| 6 | Juvenile Cod | 1,080 | Midwater Trawl |
| 7 | Haddock | 1,080 | Lobster Trawl |
| 8 | Saithe | 1,080 | Herring Seine |
| 9 | Redfish | 2,400 | Capelin Seine |
| 10 | Greenland Halibut | 2,950 | Capelin Midwater trawl |
| 11 | Other Flatfish | 2,950 | Shrimp trawl |
| 12 | Other Dem. Fish | 850 | Dredge + Trap |
| 13 | Herring | 240 | Seal guns |
| 14 | Capelin | 243 | Harpoon |
| 15 | Other Pelagics | 1,095 | |
| 16 | Nephrops | 1,200 | |
| 17 | Northern Shrimp | 3,950 | |
| 18 | Molluscs | 1,593 | |
| 19 | Benthos | 296 | |
| 20 | Other Fish | 530 | |
| 21 | Zooplankton | - | |
| 22 | Benthic producers | 296 | |
| 23 | Phytoplankton | - | |
| 24 | Detritus | - | |

appropriate rate of return to use for discounting. By developing this line of thought, Weitzman suggests that it may be essential to incorporate declining discount rates into any CBA methodology for evaluating long-term environmental projects. This paper provides another rationale for discounting long-term environmental benefits at lower discount rates from the perspective of the current generation. Pontecorvo (2001) categorically states that the desirability of restoration of stocks, e.g., as incorporated in the Magnuson Act (Anon. 1996), raises serious questions about the discount rates and the time horizons to be utilized in managing the resource. This paper proposes an approach that attempts to resolve this concern.

## Generational Cost Benefit Analysis

The proposed Generational CBA approach is based on the argument that, due to the length of time that would normally be required for depleted marine ecosystems to be restored after cessation or substantial reduction in fishing activities, the cost of such projects would be felt immediately while the benefits of restoration will accrue much later in the time horizon of the restoration effort. This difference in when the costs and benefits of restoration projects are incurred and received, would in most cases, lead to the discounted cost of restoration being higher than the discounted benefits from restoration. The way to deal with this, I argue, is to apply different discounting clocks to calculate the flows of benefits that accrue to different generations, as expressed by equation (3) below:

$$NPV = NPV_1 + NPV_2 + NPV_3 + .. + NPV_L$$
$$= \sum_{t=1}^{t_1} \frac{V_t - C_t}{(1+\delta)^t} + \sum_{t=t_{1+1}}^{t_2} \frac{V_t - C_t}{(1+\delta)^{t-t_1}} + \sum_{t=t_2+1}^{t_3} \frac{V_t - C_t}{(1+\delta)^{t-t_2}} + .. + \sum_{t=t_{L-1}+1}^{t_L=T} \frac{V_t - C_t}{(1+\delta)^{t-t_{L-1}}} \tag{3}$$

where t=0, 1, 2, ...T (the terminal period in the analysis); $0 = t_0 < t_1 < t_2 < .. < t_L = T$ are the points in time when the generations come into existence; and L is the last generation included in the analysis. Equation (3) states that the total NPV from a restoration project is the sum of NPVs that accrue to each generation, discounted using their own clocks, which start when the generation comes into existence and stops when they cease to exist.

The rationale for this is both simple and intuitive. The benefits to the current generation from the use of ecosystem resources today would never have appeared in the Conventional CBA of the generations that were here a hundred years ago. Similarly, the generation that will be here in a hundred years time, would receive benefits from restored marine ecosystems that would mean much to them but would not appear in the current generation's Conventional CBA. Therefore, to capture the benefits to all generations from ecosystem restoration projects, it is necessary to use the CBA approach expressed in equation (3) rather than that in equation (2).

## A Hypothetical Example

Consider a generic marine ecosystem, for example, that of Iceland (see Mendy and Buchary, 2001). The ecosystem contains various groups of marine creatures. Some of these creatures feed on other creatures (predator-prey relationship), while some eat their own kind (cannibalistic behavior). In addition, there are a number of fisheries operating different vessel gears in the ecosystem.

Twenty four different groups of marine creatures, and fourteen different fleet types are incorporated into our hypothetical model (see Table 1). The 'past' (1950) and 'present' (2000) states of this generic ecosystem are captured first by using Ecopath and Ecosim as described earlier. Two scenarios are developed and used to compare the benefits from restoration, namely, the status quo and restoration: Under the status quo scenario, the present-day model is run for 100 years into the future, using the present day fleet structure. In the case of the restoration scenario, simulation of the present-day model with different configurations of fleets and fleet sizes is first carried out to determine the configuration that best meets the stated restoration goal, are carried out for a

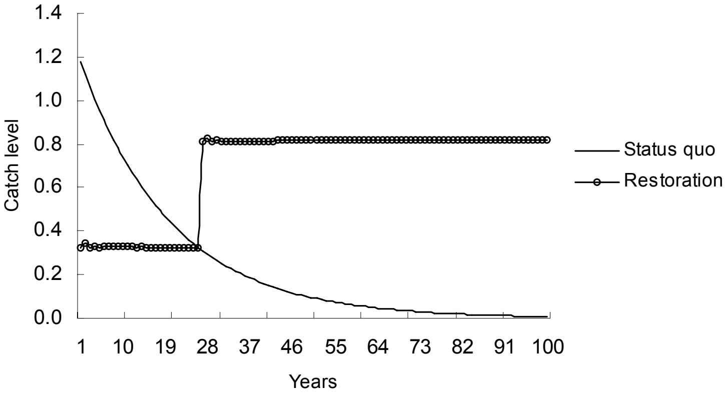

**Figure 1.** Profile of catches over 100 years.

period of 100 years. It turns out that the restoration program that gives the best results required the line fishers, gill netters, bottom trawlers and the capelin seiners to be retired from fishing for 25 years, and then re-introduced into the fishery after 25 years with only 50% of their year 2000 fleet capacities. All other vessel types are allowed to continue fishing with their year 2000 fishing capacities.

*Economic valuation of the outcomes under the status quo and restoration regimes*

The catches from the above simulations are valued by applying prices per unit of species group landed (see Table 1). From this, we subtract the cost of catching and landing the fish, which is assumed to be about 40% of the price per unit weight of a fish group. Thus, we focus only on market values in this paper. This choice of focus is deliberate, as it makes it possible to show that, in most cases, restoration efforts can be justified using market values alone, provided net benefits are counted from the perspective of the generation to which the benefits accrue. To produce the results presented below, a discount rate of 7% is applied. However, because the discount rate is very central to the argument presented in this article, we carried out sensitivity analysis on this parameter for rates of 0 to 20%. Valuation of net benefits from the two models was carried out using both the Conventional and the Generational CBA. The calculations were made under the assumption that benefits would accrue to two non-overlapping generations each of 50-year life span. We then relax the non-overlapping generation assumption by continuously introducing annually a new generation of 50-year life span for the next 50 years. The NPVs from restoration are then calculated as seen by each of these generations using their respective discounting clocks.

## Results

### *Catch profiles*

Figure 1 presents the predicted flow of catches in each 100-year simulation of the status quo and restoration models. The model predicts high initial total catches under the status quo model. But this declines steadily from year to year until it approaches zero by the end of the 100-year simulation. On the other hand, catches start low in the restoration model, and remain so for 25 years, after which the ecosystem has been restored and the retired fishing fleets are re-introduced into the fishery. The restoration effort then starts to pay off with higher steady catch levels until year 100.

### *Net benefit profiles*

We see from Figure 2 that when the Conventional CBA approach is applied, net benefits are high initially but decline rapidly, approaching zero by year 35, under the status quo scenario. The picture differs slightly under the restoration scenario. Here, benefits start low and decline slowly until year 26 when they receive a sudden increase signaling the end of the restoration effort and the re-entry of the retired fleets into the fisheries. It should be noted that in both the status quo and restoration scenarios, benefits that accrue to the future generation, that is, after year 50, count for nothing even though their harvests are high under the restoration model (see Figure 1).

On the other hand, when the Generational CBA

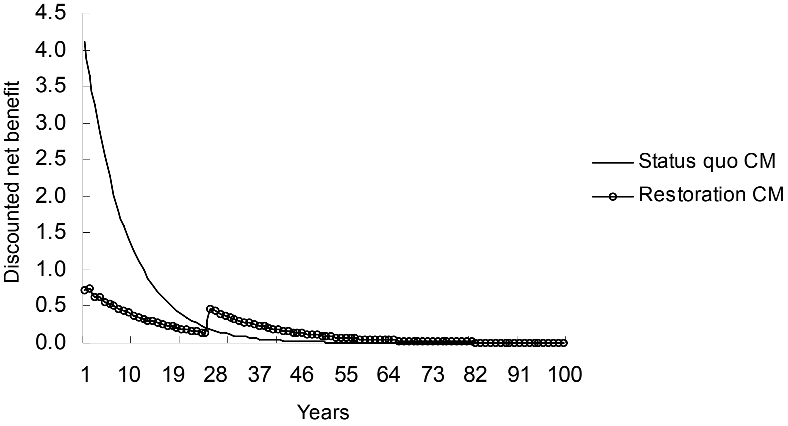

**Figure 2.** Net discounted benefits obtained using the Conventional CBA (CM).

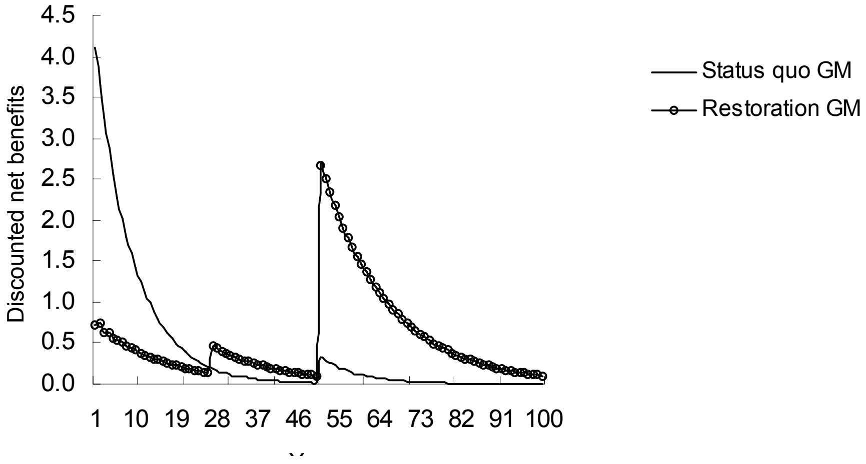

**Figure 3.** Net discounted benefits obtained using the Generational CBA (GM).

approach is applied, net benefits start very high under the status quo regime but decline in the same fashion as when the Conventional CBA is used until year 51 when the next generation comes into existence and start discounting their benefits from this time onwards (see Figure 3). For the restoration model, net benefits start low and decline until year 25, when benefits jump due to the re-entry of the retired fleets into the fishery. Then in year 51, we see a big increase, this is when the second generation comes into existence, and the flow of benefits is discounted using their own clock.

Figure 4 presents the total net present value obtained in the 100-year period of the simulation under the restoration and status quo models using the Conventional and Generational CBA approaches. We see from the figure that restoration would not be worthwhile if the Conventional CBA is used, while it would be economically sensible to undertake restoration when the Generational CBA is applied.

## *Impact of changes in discount rates*

The discount rate is the single most important parameter in this analysis. Hence, we carried out sensitivity analysis by varying it from 0 to 20% (this covers a realistic range in practice). Figure 5 present the results obtained using the Conventional and Generational CBAs, resp-ectively.

We can make the following observations from this figure:

1. The Conventional and Generational Models both favor restoration when discount rates are low – in this example between 0 and 3%.
2. The Conventional Model does not support restoration for high discounts – here, rates greater than 3%.
3. The Generational Model comes out in favor of restoration for discount rates ranging between 0 to about 15%. It comes out about neutral for discount rates between 15 to 20%.

## *Net present value of benefits as seen by each of 50 overlapping generations*

Figure 6 plots the total net present value of benefits as seen by each generation (i.e., year class) as they come into existence. To obtain the graph, the flow of benefits from restoration, as seen by each generation using their respective discounting clocks, over their assumed 50-year life span is summed and plotted.

This figure reveals that based on the benefits each generation perceives, earlier generations in this example (up to generation 12, that is, the generation to arrive 12 years from now), would come to the conclusion that restoration is not economically sensible. But later generations would definitely find restoration to be a sensible proposition. When the interests of all generations are taken into account, however, restoration becomes the preferred course of action, since the area under the 'Restoration curve' is much larger than that under the 'Status quo curve'. Figure 3 brings to the fore, in a very clear way, the important point that choosing to restore marine ecosystems is a choice to invest in the future, while choosing

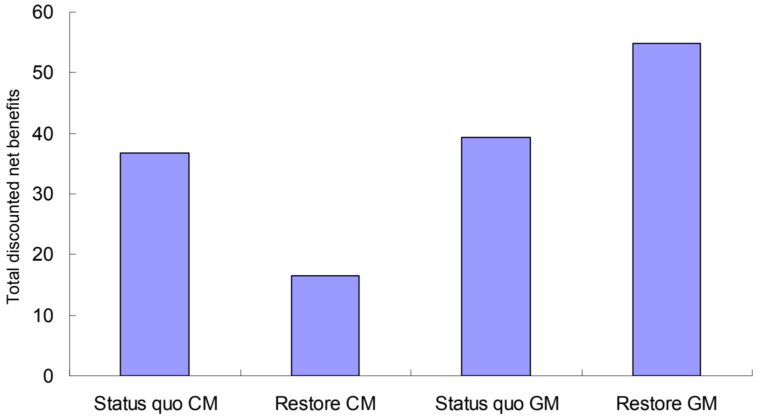

**Figure 4:** Total net present value of benefits over 100 years (CM = conventional CBA; GM is Generational CBA).

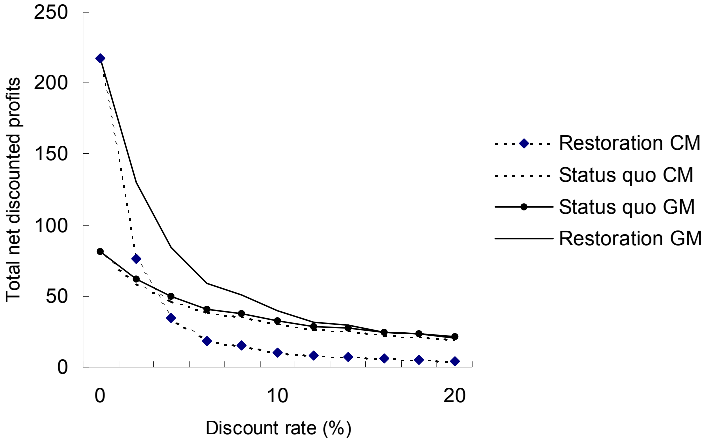

**Figure 5** Effect of discount rates.

to keep doing things as usual is a decision to disinvest.

## Concluding Remarks

This paper has proposed a CBA approach denoted as Generational CBA that takes into account that benefits from the restoration of marine ecosystems may flow not only to the current generation but also to future generations. It argues for the benefits to accrue to future generations to be discounted from their time perspective rather than that of the current generation.

Through the use of a generic model, it is shown that at low discount rates (0 to 3% for the example in this paper), both the Conventional and Generational models produce the outcome that restoration is a sensible economic proposition. At higher discount rates (over 3%), however, the Generational CBA still shows that restoration is desirable and beneficial to society while this is not the case with the Conventional CBA approach.

The ideas in this paper will be developed further in future work and applied to models of real marine ecosystems from around the world. I also plan to develop both analytical and game theoretic models based on the ideas of this paper. This would allow the extension of the Generational CBA approach to bioeconomic models. Finally, it appears that Generational CBA has a conceptual link with the shifting baseline idea of Pauly (1995). I will explore these linkages in future work.

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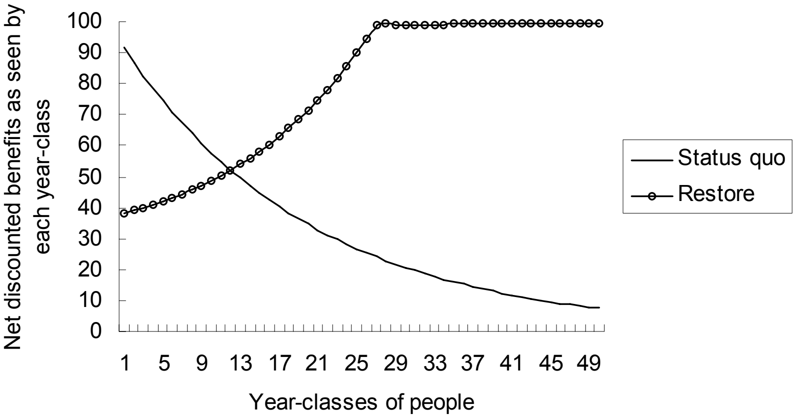

**Figure 6.** Net Present Value (NPV) as seen by each of 50 overlapping generations.

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