Discounting of Long Term Costs: What Would Future Generations Prefer Us to Do?

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Abstract

Decisions with intergenerational consequences may leave future generations worse off (i.e., not be Pareto optimal) if costs and benefits are not discounted correctly. We point out that this happens if the conventional social discount rate is applied to intergenerational costs: with this rate the justification of intergenerational costs (benefits of a project are invested and the proceeds can cover future costs) leads to an inconsistency over the long term (eventually the supposed benefits of any project become larger than the entire GNP). The conventional approach commits an error of double counting by treating the time preference component of the discount rate as if it represented creation of wealth while it really involves only redistribution. The time horizon of the redistribution is limited by the duration of market transactions, especially loans. Thus we recommend a two-step discounting procedure, with the conventional social discount rate for the short term (about 30 years) and the growth rate of the economy for the long term. Data for GNP per capita growth in the US, the UK, France, Germany, Japan and the Soviet Union since the industrial revolution, combined with data for net economic welfare per capita suggest an intergenerational discount rate in the range of 1 to 2%. For practical application the rate at which costs and benefits will grow over time is just as important as the discount rate; only the difference between these two rates matters. For many environmental costs these rates may be close to each other, during the next few generations; this implies that some of the uncertainty in the prediction of rates cancels and one can treat the problem as if the effective rate were close to zero. The consequence for costs such as global warming or nuclear power can be very significant: the valuation can increase by more than an order of magnitude compared to values based on conventional discounting.

Key words: discounting; economic growth; environmental costs; intergenerational equity; social discount rate; cost-benefit analysis.

1. Introduction

The most troubling and controversial environmental impacts are those that can affect future generations [1]. The question of discounting is crucial for any decisions in this matter because the balance of costs and benefits can be totally altered by the choice of the discount rate. The problem is epitomized by the case of nuclear power where the legacy of radioactive waste may burden our descendants over millions of years. But even our use of fossil fuels may, through the greenhouse effect, impose severe costs on several generations.

The approach of conventional economic practice is to discount all costs and benefits at the social discount rate, with typical values in the range of 3 to 8% [Lind 1982, Howe 1990, Portney 1990, Quirk and Terasawa 1991] [2]. This is highly controversial because future costs are reduced so much that most noneconomists reject the entire analysis, feeling that it fails to take the interests of future generations into account [Costanza and Wainger 1991]. As a typical expression of this criticism of intergenerational discounting we cite the statement "...use of a social discount rate greater than zero leads ultimately to a disenfranchising of future generations" in the *Highlights: Synthesis of the Issues* chapter of the Expert Workshop on Life-Cycle Analysis of Energy Systems [OECD 1992].

While the literature on this subject is long and inconclusive [see e.g. Ramsey 1928, Markandya and Pearce 1988], we believe we can add a fresh perspective by asking what future generations would prefer us to do. Our paper is motivated by the fact that the decision process through which we will affect future generations involves an analysis of the benefits and costs of proposed projects (including uncertainties) as perceived by the decision maker [3]. The situation is analogous to that of parents who must make a decision that will affect their children before the latter can express their own preferences. It is difficult to imagine a better approach than trying to the best of one's ability to estimate the costs and benefits imposed on the descendants. Despite the obvious difficulties of trying to predict future preferences, the underlying concept of costs and benefits is universal, as demonstrated by its success in explaining even the behavior of animals [Alcock 1989].

Thus we focus pragmatically on the needs of decision makers, rather than trying to solve the discount rate problem in its generality, or trying to define criteria of sustainability [for a recent review see Krautkraemer et al. 1993] and intergenerational equity [see e.g. Solow 1986, Howarth and Norgaard 1992 and 1993]. We develop a two-step discounting procedure

[1] For example, according to a recent opinion poll [Eurobarometer 1993, p.34] the possibility of irreversible consequences for future generations is the most widely stated reason for considering an environmental impact serious.
[2] All rates in this paper are real, i.e., above inflation, and stated as %/year.
[3] For example, the choice of energy paths will be influenced by the results of a major international project to evaluate the external costs of fuel cycles, the joint Accounting Framework Program of the CEC and the US DOE [ORNL/RFF 1994, EC 1995; see also an analogous study by Rowe et al 1995], in which the author is participating [Curtiss at al. 1995]. One of the findings of this program is that intergenerational effects for nuclear and for fossil fuels can dominate the external costs, depending on the choice of the discount rate. To deal with this issue, the ground rule was adopted of carrying out the valuation for three discount rates: 0%, 3% and 10%. The present paper shows that the range can be narrowed considerably.

that is compatible with the current practice of discounting within our generation, yet respects the interests of future generations. [4]

We begin, in Section 2, by pointing out an inconsistency in the traditional justification of discounting (benefits of a project are invested and the proceeds cover future costs) when the conventional social discount rate is applied to intergenerational costs (eventually the supposed benefits of any single project become larger than the entire GNP). The conventional argument commits an error of double counting by treating the time preference component of the discount rate as if it represented creation of wealth while it really involves only redistribution. The time horizon of the redistribution is limited by the duration of market transactions, especially loans. Only the growth component of the discount rate is relevant for a cost-benefit analysis from the point of view of future generations.

Therefore we propose a discounting procedure that uses the conventional rate up to a time horizon t_{short} (about 30 years) and a reduced rate beyond t_{short}. As shown in Section 3, a cost-benefit analysis from the perspective of future generations implies that the preferred rate beyond t_{short} is the growth rate r_{gro} of the economy. To find guidance for the choice of a numerical value we examine, in Section 4, data for GNP growth of the US, the UK, Germany, France, Japan and the Soviet Union since the industrial revolution. Assuming that population growth cannot continue indefinitely, we focus on the growth of GNP per capita. Together with data for net economic welfare, available for the US, this leads us to recommend rates in the range of 1 to 2%.

To highlight the consequences we point out, in Section 5, that the discount rate r_{dis} is only one of a pair of elements that effect the analysis equally. Before discounting one must predict the rate r_{esc} at which future costs and benefits will grow. Formally the result looks as if one had simply discounted at an effective rate $r_{eff} = r_{dis} - r_{esc}$. Many environmental costs can be expected to grow at a rate between 0 and r_{gro}. If, as is likely for the next few generations, r_{esc} is fairly close to the latter, some uncertainty of the predictions cancels. Thus in some cases our recommendation is in effect not far from the approach advocated by many environmentalists: one can treat certain long term costs with an effective rate r_{eff} which close to zero.

Apparently our proposal is not new, even though we have not found any specific references. We believe that the proposal has not gained favor because the double counting error of the conventional argument has gone unheeded.

2. Critique of Conventional Discounting

Suppose an investment project entails a single benefit B (net of investment) at time t = 0 and a single cost C at time t = N. Discounted at rate r, the net present value is

$$P = B - \exp(-r\, N)\, C \tag{1}$$

[4] Our analysis concerns only public investments, since there are essentially no private investment decisions (other than intra-family) where intergenerational costs are taken into account.

The project is beneficial if and only if $P > 0$. It is instructive to look at the future value F of this project at time $t = N$

$$F = \exp(r N) P = \exp(r N) B - C \quad . \tag{2}$$

This equation highlights the traditional justification for the discounting of long term costs: the benefit B can be invested at rate r and the resulting future value is available to pay for the future cost C. We accept this justification for the principle of discounting.

However, we disagree with the practice of using for r the conventional social discount rate when intergenerational effects are involved. Roughly speaking the discount rate r arises from two distinct phenomena: the preference for present over future consumption, and the growth of the economy. This is often expressed in the classic equation (see e.g. Nordhaus 1991)

$$r = r_{pref} + \eta \, r_{gro} \tag{3}$$

where
r_{pref} = pure rate of time preference,
r_{gro} = growth rate of real income,
and

$$\eta = - \frac{u''(c)\, c}{u'(c)} \tag{4}$$

is the elasticity of marginal utility of income, where u(c) is the utility of the consumption c. For the social discount rate it is reasonable to take values of these parameters in the vicinity of 3% for r_{pref}, 1 for η (which corresponds to a logarithmic form of u(c)), and 2% for r_{gro} (= rate of GNP growth), resulting in a discount rate r of 5% (see e.g. Nordhaus 1991).

In models of economic growth the parameters in Eq.3 are generally not independent. For example, r_{pref} influences savings and investments which in turn influences r_{gro}. In the present paper the relation between time preference and r_{gro} is of no concern, for several reasons. First of all, we are looking at a project from the perspective of the future. Looking back at any period, one can simply take the values of r_{pref}, η and r_{gro} experienced during this period as given, regardless of how they may be related or whether they have been calculated by an economic model or extracted from historical data. Secondly, if our two-step discount procedure is implemented the effect on growth is negligible because only intergenerational costs are affected and these account only for a small part of the economy (and the effect would arise only from differences in total investment due to intergenerational costs).

Now, looking at F of Eq.2 from the perspective of the future, we se that there is an inconsistency if any rate r greater than the GNP growth rate r_{gro} is used for a sufficiently long time: eventually the annual benefit r exp(r N) B becomes larger than the entire GNP - clearly an absurdity. If one expresses B as a fraction of GNP, the time N_x at which the interest begins to exceed the GNP is readily found by solving

$$\exp(r_{gro}\, N_x) = r \exp(r\, N_x)\, B \quad . \qquad (5)$$

To show that this has practical relevance, let us insert numbers that correspond to the nuclear power program in France - with some simplifications to render the argument more transparent. In particular let us assume steady state conditions where the plants are replaced at a constant rate, each lasting 30 years. The annual investment cost I for this replacement amounts to approximately I = 0.33% of GNP, based on the following data: GNP = US$ 1.2×10^{12} in 1990 [USDOC 1992], nuclear capacity = 60×10^9 W, and investment cost US$ 2/W [Ministère de l'Industrie 1993] spread over 30 years. Since we are focusing on intergenerational costs, let us interpret B in Eq.1 as the net present value of this investment calculated without intergenerational costs. The exact value of B depends on details of costs components that are not of interest here. For the present purpose it is sufficient to assume a value for the ratio of B/I (the benefit-cost ratio excluding intergenerational costs). We assume a value of B/I = 3.3 as an approximate value implied by cost data for nuclear power in France [Ministère de l'Industrie 1993, EdF 1994]. Thus B = 1.1% of GNP, and Eq.5 yields $N_x = 250$ years. This result is not very sensitive to B/I and in any case the precise numbers do not matter: the point of this exercise has merely been to demonstrate that the justification of conventional discounting breaks down well within the time span over which it is supposed to be valid.

At what point does this breakdown occur? Before N_x, but not within the present generation: the benefits can indeed be invested to bear interest at rates comparable to the social discount rate r because there exist financial instruments such as bonds that offer such returns over durations up to 30 years. This interest comes from two sources, reflecting the two components of the discount rate: there is the money people pay to be able to consume now rather than in the future, and there is the gain from economic growth. Only the latter represents creation of wealth; the former merely redistributes it. Assuming constant rates, the gain from growth continues forever. But the money from redistribution is a limited pool, essentially paid by each generation for its own consumption preferences. It would be an error of double counting to consider it as income forever.

The temporal boundaries of this redistribution are fuzzy because generations overlap and different loans have different durations. Any particular loan of duration N years redistributes money over a period of N years, and the redistributive contribution of this loan to the social discount rate stops with the end of the loan. Thus the time preference component of the discount rate cannot not be counted for the compensation of damages beyond the duration of the loans that are active at the time when a project is chosen. There is a large market for loans up to 30 years (e.g., residential mortgages in the US); in addition there are funds for retirement, which run over longer periods, in some cases up to about 70 years between pay in and pay out. The longer the time span between pay in and pay out, the smaller the number of transactions.

Within the present generation the conventional rate is justified by the existence of a market of borrowing and lending activities which expresses the preferences between current and future consumption. There is no intergenerational market, and only the growth component of the discount rate is relevant for a cost-benefit analysis from the point of view of future generations. Without a market where intergenerational preferences can be expressed, the role of r_{pref} and u(c) in Eq.3 becomes irrelevant beyond t_{short}. Thus the discount rate can be one of the parameters in a cost-benefit analysis that change with time.

3. Cost-Benefit Criterion of Future Generations

Note that the absence of a market does not rule out the possibility of compensation from the present to the future. Therefore the basis of the cost-benefit approach is valid even for intergenerational effects. In particular, one can make the ethical choice that the decisions of the present generation be Pareto-optimal for future generations, i.e. no future generation should be made worse off. [5]

These considerations lead us to propose a two-step discounting procedure, using the conventional rate up to a time t_{short} (for which 30 years appears reasonable), followed by a reduced rate for intergenerational effects. Such a change in the discount rate may appear to conflict with the expectation that one obtain future loans at real interest rates comparable to current loans and the fact that the sequence of two loans for the same amount and the same interest rate, one over the first N_1 years, the other over the following N_2 years, is mathematically equivalent to a single loan over $N_1 + N_2$ years. However, this mathematical equivalence does not correspond to economic reality because there is no market of intergenerational loans.

Let us designate by P_{short} the net present value of the project, calculated from the selfish perspective of the generation that makes the decision. Thus P_{short} is the value at the time of the decision; it is calculated with the short term discount rate r_{short} (= r of Eq.3) and excludes any costs beyond t_{short}. Of course, the project is cost effective within this perspective if P_{short} is positive; in other words the short term decision criterion is

$$\text{cost-benefit criterion of present generation: } \textbf{yes if } \mathbf{P_{short} > 0} \quad . \qquad (6)$$

If the project is realized it can be considered to increase the GNP by P_{short} at the time of the decision (temporal details of its contribution to the GNP do not matter when seen from the distant future). Henceforth one can assume P_{short} to grow at the average growth rate r_{gro} of the GNP. This growth determines the future benefits that will be available to compensate intergenerational costs.

In principle the growth rate could be different for different projects, different places and different times, involving different mixes of labor, capital and natural resources. For example, a biomass plantation and a petroleum refinery may stimulate different growth patterns. In the present paper we will not try to disaggregate such effects, and we will only determine a single average growth rate. This seems appropriate since during the period up to t_{short} much of the growth effects from a project will have diffused throughout the economy.

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[5] The distribution of costs and benefits between individuals within a given generation is the responsability of each generation.

Consider this project in the years beyond t_{short}, supposing the cost in year t to be C(t) (the argument holds equally if there are benefits beyond t_{short}). In the year t the amount P_{short} will have grown to $P_{short} \exp(r_{gro} t)$. The net benefit in the year t is obtained by subtracting from this value the costs incurred after t_{short}. These costs must likewise be corrected because their effect also grows at the rate r_{gro}. The net benefit in the year t is therefore

$$B(t) = P_{short} \exp(r_{gro} t) - \int_{t_{short}}^{t} dt' \, C(t') \exp(r_{gro} (t-t')) \tag{7}$$

where the exponential in the integral reflects the fact that the effect of the cost C(t') grows at rate r_{gro} from t' to t. A generation in year t prefers us to choose the project if and only B(t) is positive. This is the case if and only if the quantity

$$P_{long} = [P_{short} - \int_{t_{short}}^{t} dt' \, C(t') \exp(-r_{gro} t')] \tag{8}$$

is positive. Therefore we obtain the criterion of the future generations as

$$\text{cost-benefit criterion of future generations: } \mathbf{yes\ if\ P_{long} > 0} \quad . \tag{9}$$

This has a simple interpretation. The right hand side of Eq.8 is formally the same as the present value of a project that brings an initial benefit P_{short}, followed by a series of costs beyond t_{short} that are discounted at the rate r_{gro}. Thus we obtain the cost-benefit criterion of future generations if we discount the costs beyond t_{short} at the rate r_{gro}. A project satisfies intergenerational Pareto-optimality if and only if Eq.9 holds for each future generation.

4. Data for r_{gro}

To apply this one needs to predict the growth rates for the future. Economic growth is a complex phenomenon. There is no guarantee that the GNP will grow. Capital could be invested wisely, squandered on worthless consumption or even destroyed by warfare; obviously the corresponding growth will be very different. In this paper we do not try to predict r_{gro} from first principles. Rather, we look for guidance in past history. Short term trends (decades or less) appear irrelevant, but averaged data since the industrial revolution may not be inappropriate for the next centuries, despite overpopulation, environmental degradation and depletion of resources - Malthusian worries that were just as prevalent two hundred years ago. The last two centuries have seen appreciable growth, several horribly destructive wars notwithstanding. Is there reason to expect less growth now that we are on the threshold of the computer revolution, that family planning is ever more widely practiced, and that the civilized world has learned the lessons of war and peace? Of course, there is no guarantee. Rome was overrun by barbarians - and yet a renaissance ensued.

In trying to predict future growth, one needs to distinguish population growth from other components of growth, because the population explosion since the industrial revolution is likely to come to an end. Even if technological progress allows the continued expansion of the supply of food and other resources, there is one limitation for which an expansion is difficult to imagine: the availability of land, in view of people's demand for "open space". For that reason we take the growth rate of GNP per capita as guide in choosing r_{gro}.

Some data for long term average GNP growth can be found in the classic textbook of Samuelson and Nordhaus [1985], as well as in Toutain [1987]. We present their data in Table 1, together with data for population growth from McEvedy and Jones [1978] and USDOC [1992]. The growth rate for GNP per capita is the difference between the first two columns.

Table 1. Average growth rates in %/yr for GNP, population and GNP per capita.

Country period	GNP	Population	GNP/cap
France			
1789-1982			**1.5** [f]
1949-1982			**3.6** [f]
Germany			
1850-1984	2.8 [a]	0.9 [d]	**1.9**
Japan			
1874-1929	4.5 [a]	1.0 [d]	**3.5**
Soviet Union			
1885-1913	3.3 [a]	1.0 [d]	**2.3**
1928-1983	4.9 [a]	0.7 [d]	**4.2**
United Kingdom			
1855-1984	2.1 [a]	0.8 [d]	**1.3**
USA			
1800-1984	3.5 [b]	2.1 [e]	**1.4**
1890-1984			**1.8** [c]

[a] Table 35-1, p.776, of Samuelson and Nordhaus [1985];
[b] p.79, of Samuelson and Nordhaus [1985];
[c] Fig.25-1, p.562, of Samuelson and Nordhaus [1985];
[d] McEvedy and Jones [1978];
[e] USDOC [1992].
[f] Toutain [1987].

The highest rates in this table are 4.2% for the Soviet Union and 3.5% for Japan, as well as 3.6% for France in the decades after World War II. These rates may reflect unique historical circumstances of catching up from a low position relative to richer countries. Furthermore, Japan may be unusual with an exceptionally high ratio of savings over consumption, and one may have doubts about the reliability of data from the Soviet Government. The long term average rates for France, Germany, the United Kingdom and the USA are much lower, between 1.3 and 1.9%.

Now to the question whether GNP is an appropriate measure of wealth. It is obviously flawed, failing to account for such phenomena as the underground economy or the damage from pollution. Alternatives have been proposed, in particular the Net Economic Welfare index, but they are not yet universally accepted and data are much more limited. Here, too, an interesting data point is cited by Samuelson and Nordhaus [1985] which we show in Table 2: from 1929 to 1984 the Net Economic Welfare per capita of the US grew at an annual rate of 1.1% while the corresponding growth rate of the GNP per capita was 1.7%.

If one disregards the high GNP growth rates for Japan and the Soviet Union as being less representative than the long term data for the other countries in Table 1, and if one takes the point of view that the relevant rate should perhaps be reduced towards the NEW/GNP ratio of Table 2, then one is lead to the conclusion that values of r_{gro} in the range of 1 to 2% may be a good guess. This range is clearly much lower than the values in the range of 3 to 8% usually recommended for the social discount rate [Lind 1982, EPA 1983, Howe 1990, Quirk and Terasawa 1991]. To appreciate the significance of this difference in rates, one needs to consider the evolution of costs.

Table 2. Average growth rates in %/yr for GNP and NEW (Net Economic Welfare) per capita, for US from 1929 to 1984.

From Fig.6-4, p.119, of Samuelson and Nordhaus [1985]

GNP/cap	1.7
NEW/cap	1.1

5. The Evolution of Costs

Before discounting a cost one must estimate its value; this involves extrapolation from currently known costs. If one makes the customary assumption of constant growth rates, a cost C(t) that occurs at time t is calculated by applying a factor $\exp(r_{esc}\, t)$ with an escalation rate r_{esc} to the value C(0) that has been determined at time 0 (the present). Then one divides by a factor $\exp(r_{dis}\, t)$ with discount rate r_{dis} to obtain the present value

$$\text{present value of } C(t) = C(0) \exp((r_{esc} - r_{dis})\, t) \quad . \qquad (10)$$

Only the difference

$$r_{eff} = r_{esc} - r_{dis} \qquad (11)$$

matters. Even though this point is obvious and has been noted before, for instance by Fisher and Krutilla [1975], almost all of the environmental literature has been preoccupied with the discount rate while neglecting r_{esc}. Let us sketch some possibilities. For many intergenerational environmental costs, such as health impacts and global warming, a plausible value of the escalation rate is $r_{esc} \approx r_{gro}$, at least in the intermediate term (the next few generations). The reason is that their valuation is based on willingness-to-pay (WTP), and as such it can also be expected to be approximately proportional to GNP/capita.

Quite generally WTP can be considered to evolve in two ways: firstly it is proportional to per capita wealth, secondly the constant of proportionality may change due to shifts in preferences or costs. The fraction of wealth spent on any one item can increase, but certainly not beyond 100%. Since over the long term an exponentially growing term will exceed any constant, r_{esc} cannot be larger than r_{gro}. This implies that the net rate r_{eff} in Eq.11 should not be negative.

One also needs to consider the possibility of adaptive measures that allow us to reduce the impacts of environmental burdens. For example, if a cure for cancer is found, it would not be appropriate to apply today's valuation of cancers beyond that time. Thus in the very long run the costs may become small or negligible. A positive value of r_{eff} is compatible with this possibility, a value of zero is not.

These considerations lead us to recommend a simple working rule: forget about the escalation rate and calculate the intergenerational costs (beyond t_{short}) as if the discount rate were close to but slightly above zero, and in any case no larger than r_{gro}

$$0 < r_{eff} < r_{gro} \approx 1 \text{ to } 2\%, \text{ probably } r_{eff} \text{ close to 0 for next few generations. .} \qquad (12)$$

An attractive feature of this argument is that uncertainties due to the prediction of growth rates cancel approximately.

Now the break from conventional discounting becomes manifest: with conventional discounting the effective rate is several percent higher than zero while the discount procedure recommended here yields an effective rate close to zero. The consequence for the assessment of intergenerational costs can be dramatic: the present value of an infinite series discounted at rate r_{eff} is proportional to $1/r_{eff}$.

6. **Conclusion**

We have shown that the justification for the discounting of long term costs of a project involves an inconsistency if the conventional social discount rate is applied beyond the generation that chooses the project. If one makes the public policy choice of accepting the cost-benefit perspective of future generations, one finds that costs beyond the first generation should be discounted at the growth rate of the economy. The transition time between short term and long term rate is determined by the duration of loans, and a time of 30 years appears reasonable.

Contrary to the common belief of many environmentalists, discounting does not disadvantage future generations if this two-step discounting procedure is adopted. The cost-benefit criterion of Eqs.8 and 9 assures intergenerational Pareto-optimality by giving each future generation a veto over our decisions. In fact, if we do not discount, future generations could chide us for decisions that make them worse off. But we have also pointed out that, when all relevant growth rates are taken into account, our procedure may often be quite close numerically to the position of people who are against discounting. The consequence for costs such as global warming or nuclear power can be very significant: the valuation can increase by an order of magnitude compared to values based on conventional discounting.

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