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Against High Discount Rates

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ABSTRACT

In the economics of climate change, the future benefits of greenhouse gas emissions abatement are commonly discounted at a rate equal to the long-run return on corporate stocks, which averaged 6% per year during the 20th century. Since a 6% discount rate implies that one dollar of benefits obtained one century from the present attains a present value of less than one cent, this method implies that only modest steps towards greenhouse gas emissions are economically warranted. This chapter critiques this approach to discounting the future based on three distinct lines of reasoning. First, the use of high discount rates is inconsistent with classical utilitarianism, which holds that equal weight should be attached to the welfare of present and future generations. Second, the approach violates the principle of stewardship, which holds that it is morally unjust for present generations to engage in actions that impose uncompensated environmental costs on posterity. Third, the use of a 6% discount rate is appropriate in the analysis of public policies that have risk characteristics that are similar to those associated with corporate stocks. Economic theory, however, suggests that discount rates of 1% or less should be used to evaluate policies that reduce future risks. Since a main objective of climate change policies is to reduce the risks faced by future society, the use of high discount rates in the analysis of climate change policies is arguably inappropriate.

INTRODUCTION

The theory of discounting is based on the assumption that people's observed behavior in markets for savings and investment reveals their subjective preferences regarding tradeoffs between present and future economic benefits. A person who borrows money at the annual interest rate r, for example, shows a willingness to pay $(1+r)^t$ dollars t years in the future to obtain one dollar in the present. On the other side of this transaction, the lender demands $(1+r)^t$ future dollars in exchange for each dollar loaned out today. In the logic of this situation, both borrowers and lenders behave as if one dollar of future currency has a "present value" of just

$1/(1+r)^t$. In this expression, the interest rate r is interpreted as the prevailing "discount rate" or time value of money.

According to economists, people discount the future for a variety of reasons (Lind, 1982; Pearce, 1994). First is the concept of impatience or pure time preference. There is good evidence that this is a basic aspect of human psychology that arose in the course of human evolution (Rogers, 1994); in any event, the reality of impatience seems intuitive to most people. A second factor that supports discounting is the observation that, in a world of rising incomes and consumption levels, one dollar of future expenditure would deliver less satisfaction than a dollar spent in the present. Third, people discount the future because of uncertainty – the risk that expected benefits may fail to materialize in a world of imperfect foresight. Finally, discount rates are linked to the productivity of capital investment. In sum, discount rates reflect both people's subjective attitudes towards tradeoffs between present and future benefits and the objective benefits that arise when income is invested in assets such as new homes and production facilities.

As is well known, discounting procedures play a key role in the economics of climate change. According to standard estimates, stabilizing greenhouse gas emissions at current levels would reduce short-run economic output by 0.2-2.0% in industrialized nations such as the United States (Weyant, 1999; IPCC, 2001b). Emissions abatement is a means to reduce the future costs of climate change which – although uncertain – would likely amount to several percent of world economic output given the 1.4-5.8°C temperature increase that is projected to occur during this century (IPCC, 2001a). Since climate change response strategies involve short-run costs and long-run benefits, the identification of optimal policies depends strongly on the relative weight that decision makers attach to the interests of present and future society.

Although there are competing approaches to answering this question (see Howarth, 2001), one prominent approach is the application of conventional cost-benefit analysis. In this approach, the costs (C_t) and benefits (B_t) of public policies are measured in monetary units for each year $t = 0,1,2,\ldots$ with the initial date ($t = 0$) defined as the present. Policies are then chosen to maximize the discounted value of net benefits as summarized by the "net present value" criterion:

$$\begin{aligned} NPV &= (B_0 - C_0) + (B_1 - C_1)/(1+r) + (B_2 - C_2)/(1+r)^2 + \ldots \\ &= \sum_{t=0}^{\infty} (B_t - C_t)/(1+r)^t . \end{aligned} \quad (1)$$

For the reasons outlined above, the discount rate r is chosen based on observed interest rates and returns to capital investment.

Based on historical returns in real-world financial markets, analysts such as Nordhaus (1994b; see also Manne, 1995) argue that the discount rate should be set equal to a real (inflation-corrected) value of 6% per year. The use of real discount rates is standard practice in this literature, and is theoretically appropriate when costs and benefits are expressed in inflation-adjusted terms so that the purchasing power of one dollar is constant over time. Given current estimates concerning the anticipated costs and benefits of climate change, discount rates of this magnitude suggest that only modest steps towards climate stabilization should be undertaken (Nordhaus, 1994b; Howarth, 1998). With a 6% discount rate, one dollar of benefits obtained one century in the future attains a present value of less than one cent. Unsurprisingly, this assumption implies that it is better to bear the future costs of climate change than the short-run costs of stringent emissions reductions.

The purpose of this chapter is to critically evaluate the use of this standard (or "high") discount rate in the economics of climate change. The analysis sets forth three logically distinct lines of reasoning. First, I shall argue that the fact that *individuals* discount the future in private market decisions does not imply that policy makers should discount future costs and benefits that accrue to *future generations* (Parfit, 1983b). On moral grounds, authors such as Broome (1992) and Cline (1992) argue that equal weight should be attached to the welfare of present and future generations in environmental policy analysis. As we shall see, this value judgment implies that quite aggressive steps towards climate stabilization might be morally justified.

Second, I shall argue that the net present value criterion, when implemented using high discount rates, supports an outcome in which short-run greenhouse gas emissions reduce the welfare of future generations in comparison to a path where emissions are stabilized one-third below current levels. This result runs afoul of Brown's (1998) notion of "stewardship" – the principle that future generations hold a moral right to inherit an undiminished natural environment unless they are duly compensated for environmental harms.

Finally, I shall argue that the use of high discount rates is unjustified based on considerations of risk and uncertainty. While market decisions show that people demand a 6% annual return on risky investments such as corporate stocks, they also show that people accept much lower returns on safe investments such as U.S. Treasury Bills and corporate bonds. According to the Framework Convention on Climate Change, a key purpose of climate change response policies is to reduce the risk that climate change will impose catastrophic impacts on future generations. Since the economic theory of decision-making under uncertainty implies that public investments that reduce future risks should be evaluated using low discount rates (see Sandmo, 1972; Starrett, 1988), the use of high discount rates may be unwarranted in the context of climate change.

THE ARGUMENT FROM UTILITARIANISM

The basic argument that supports the use of high discount rates is described in the preceding paragraphs. Since private individuals demand a 6% annual return on investments in standard financial assets, public decision-makers should discount the future benefits of climate change policies at that same 6% rate in the context of monetary cost-benefit analysis. Proponents of this view argue that the use of lower discount rates would violate the principle of consumer sovereignty – the notion that people are the best judge of their individual welfare and that policy-makers should respect the preferences that people reveal in their market decisions. This reasoning assumes that market decisions are based on a rational assessment of the consequences of one's actions for one's experienced utility – an assumption that is called into question by analysts such as Norton *et al.* (1998). The notion of consumer sovereignty, however, has significant intuitive appeal, emphasizing as it does the importance of individual freedom.

In the discounting literature, however, this line of reasoning runs up against a powerful critique. While rational *individuals* may discount future benefits that accrue to them personally, it does not logically follow that policy-makers should discount costs and benefits that fall on members of *future generations* (Parfit, 1983b). In this perspective, issues of personal time preference are simply not relevant to the moral problem of adjudicating conflicts between the interests of present and future society. Instead, discount rates should be chosen based on explicit principles of intergenerational fairness.

Defenders of high discount rates have a well-articulated response to this critique. Although individual persons have finite lifespans, they assert, savings and investment decisions are managed by *households* or "dynasties" with preferences that stretch from the present into the indefinite future (Barro, 1974). In this perspective, market decisions reflect the altruistic concern that parents hold towards their children and more distant descendants. Accordingly, market rates of return reveal the preferences that present society holds regarding intergenerational tradeoffs, thus justifying the use of conventional discounting procedures.

Critics, however, have identified at least two potential flaws in this line of reasoning. On the one hand, empirical evidence does not unambiguously support the hypothesis that investment decisions are premised on a desire to transfer wealth to one's children and grandchildren. An econometric study by Hurd (1987), for example, suggests that investment behavior is best described in terms of individuals' desire to enjoy financial security in old age. Bequests to one's children – although a real phenomenon – play a minor role in explaining people's economic behavior. More deeply, Chichilnisky (1997) argues that the notion that discount rates should be based on the altruistic preferences that present society holds towards posterity constitutes a "dictatorship of the present" that denies full moral standing to members of future generations. This point mirrors the general ethical principle that moral obligations – for example the duty to alleviate the suffering of the poor and infirm – are conceptually independent of individual preferences, altruistic or otherwise.

An alternative approach to the analysis of climate change response strategies is based in the theory of classical utilitarianism, a moral framework that traces its roots to the works of Jeremy Bentham (1823) and John Stuart Mill (1863). According to utilitarians, social decisions (and hence climate change policies) should seek to maximize the total level of well-being (or "utility") experienced by all present and future persons (Broome, 1992; Cline, 1992). Although this framework is analogous to cost-benefit analysis in the sense that it aims to maximize a formal conception of the good, it differs from cost-benefit analysis in two crucial respects. First, gains and losses are measured in terms of utility as opposed to monetary units. Second, utilitarianism holds that equal weight should be attached to the welfare of present and future generations.

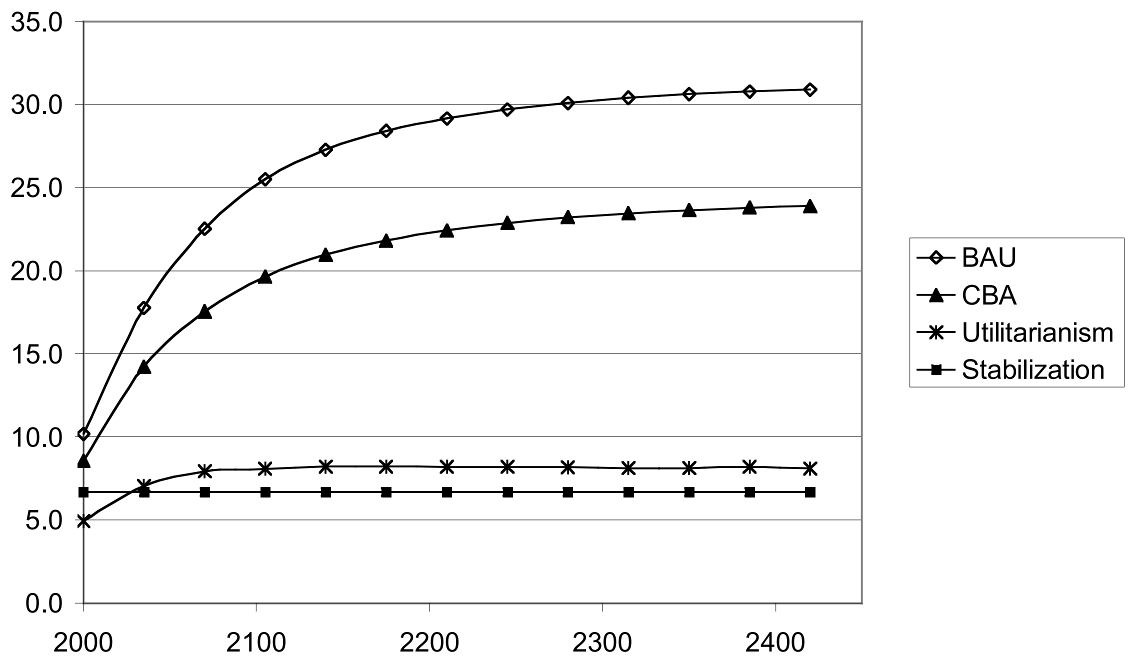
The implications of this debate for climate change policy are illustrated in Figures 1-4. These figures, which are based on Howarth's (1998) model of interactions between climate change and the world economy, compare the climate change policies that emerge under four alternative social choice rules:

1. *Business-as-usual*, which assumes that greenhouse gas emissions remain unregulated both in the present and at all future dates.
2. *Cost-benefit analysis*, which discounts the future at a rate equal to the market return on capital investment.
3. *Classical utilitarianism*.
4. *Climate stabilization*, in which emissions are maintained at a fixed level that limits long-term greenhouse gas concentrations to a doubling relative to pre-industrial levels.

In this model, decisions concerning consumption, investment, and economic production are managed by private households and businesses in the context of competitive markets. The role of public policy is limited to defining a tax on greenhouse gas emissions that strikes an optimal balance between the short-run costs and long-run benefits of climate mitigation measures. The revenues raised by the emissions tax at each date are returned to private individuals in equal payments. A further description of the model is presented in the Appendix.

As the figures show, greenhouse gas emissions grow quite substantially over time in the business-as-usual scenario. In this case, emissions rise from 10 billion tonnes of carbon equivalent (tce) in the year 2000 to 31 billion tce per year in the long-term future. Most of this increase occurs during the 21^{st} century. This emissions path leads mean global temperature to increase by 6.3°C over the next four centuries. Although this increase temperature is small when compared to seasonal fluctuations or differences between geographic regions, it is large in comparison with the changes have occurred during the Earth's geological history (IPCC, 2001c). In the context of this model, this temperature change leads to costs equivalent to 10% of long-term economic output. This figure accounts for the impacts of climate change on both market activities (such as agriculture, energy use, water supply, and real estate) and nonmarket goods

Figure 1: Greenhouse Gas Emissions (billion tce/year)



(such as human health and the functioning and integrity of natural ecosystems).

Figure 2: Temperature Increase (°C)

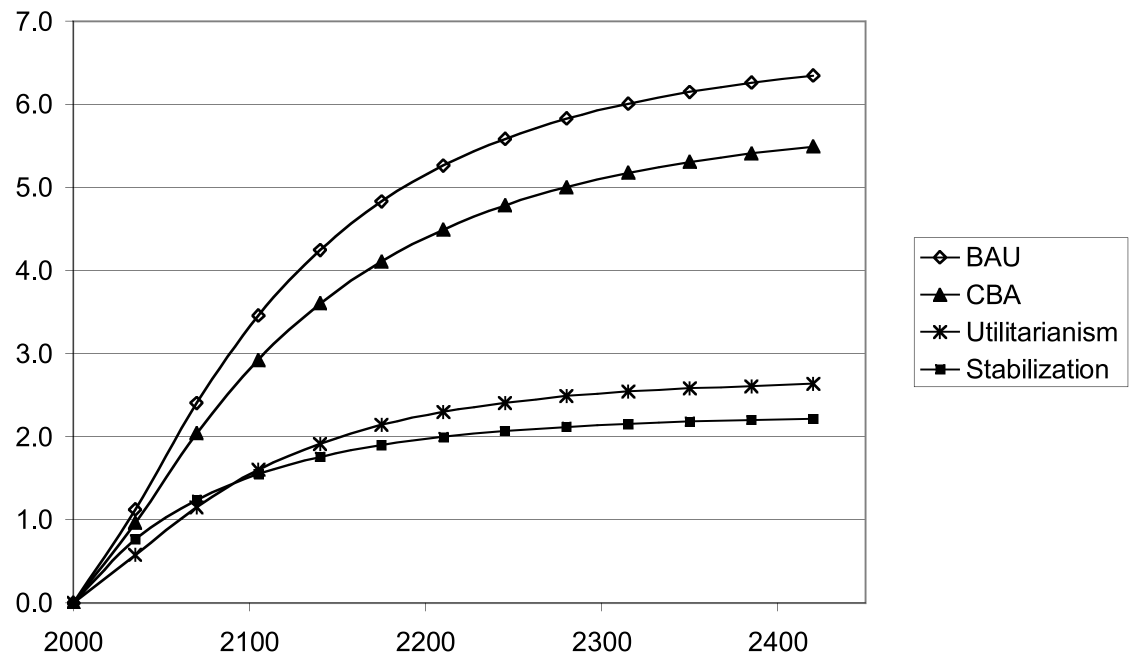


Figure 3: Emissions Tax ($/tce)

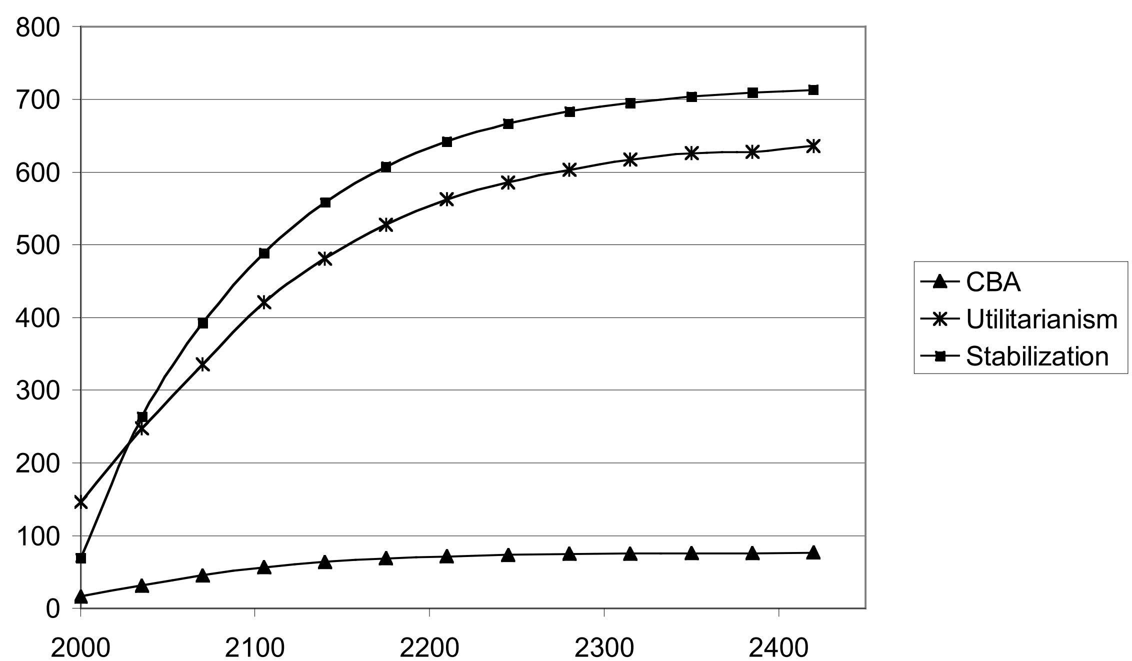
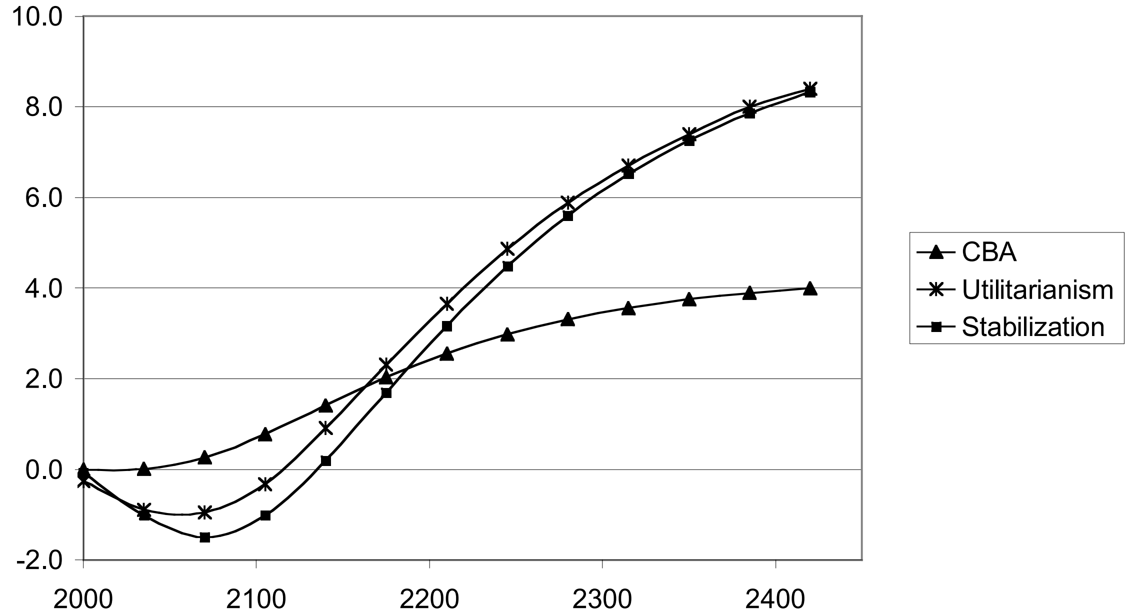


Figure 4: Net Benefits -- Change Relative to BAU (trillion $/year)



In this model, cost-benefit analysis gives rise to optimal policies that involve relatively modest rates of emissions control. In comparison with business-as-usual, emissions are reduced by 16% in the short-run and by 23% in the long-run future. These reductions are achieved through a greenhouse gas emissions tax that rises from $16/tce in the present to $76/tce in 2420. (Throughout this discussion, monetary values are measured in inflation-adjusted 1989 U.S. dollars.) Although this scenario leads to a relatively small reduction in the rate and magnitude of climate change, it confers quite substantial economic benefits on members of future generations. In the year 2105, for example, society experiences a net benefit of $0.8 trillion in comparison with the business-as-usual case, while net benefits rise to $4.0 trillion in the year 2420. Interestingly, however, this policy has almost no impact on short-run economic welfare. By way of comparison, the optimal emissions tax in the year 2000 is equivalent to a gasoline tax of just 4 cents per gallon – a figure that would allow producers and consumers to respond at a relatively low economic cost.

Classical utilitarianism, in contrast, gives rise to substantially more aggressive policies. Under utilitarianism, greenhouse gas emissions are reduced by 51% relative to business-as-usual in the year 2000. Although emissions rise gradually during the 21st century, they are stabilized at a level of 8.1 billion tce per year, a figure that is significantly below the year 2000 level under business-as-usual. This emissions path, which limits the long-run rise in mean global temperature to 2.6°C, is supported by an emissions tax that rises from $146/tce to $636/tce over the next four centuries. Relative to business-as-usual, greenhouse gas emissions abatement imposes net economic costs of $0.3 trillion in the year 2000 and $1.0 trillion in the year 2070. These short-term costs, however, give rise to future net benefits that rise to $8.4 trillion in the year 2420. These net benefits are more than twice as large as those that arise under conventional cost-benefit analysis.

These particular numerical results depend of course on empirical assumptions that are open to critical examination (Howarth and Monahan, 1996). Nonetheless, the analysis reveals the sensitivity of optimal climate change policies to changes in the discount rate. Although utilitarianism attaches equal weight to changes in present and future well-being, the utilitarian optimum described is consistent with the results that arise when a small positive discount rate is used in monetary cost-benefit analysis. Given anticipated growth in income and consumption, Cline (1992) gauges that the satisfaction provided by an incremental unit of expenditure will decline at a 1% annual rate over the course of the next century. Hence the utilitarian social choice rule may be operationalized through the use of a 1% discount rate in monetary cost-benefit analysis (IPCC, 1996).

Authors such as Manne (1995) argue that the utilitarian approach to climate change policy is "unrealistic" because, in a world of economic growth, it requires sacrifice on the part of relatively poor people (living in the present) to provide benefits to people with much higher incomes (future generations). While this argument seems plausible on its face, it overlooks an important dimension of climate change policy that is emphasized by Schelling (2000). As Schelling notes, emissions control costs would fall principally on affluent people living in industrialized nations, while the impacts of climate change would fall hardest on future peasant farmers living in developing countries who lacked the resources required to adapt to altered environmental conditions. This issue is obscured in aggregate models of climate-economy interactions that abstract away from issues of uneven development and economic inequality. This observation, however, generally reinforces utilitarian arguments that favor relatively stringent steps towards climate stabilization.

THE ARGUMENT FROM STEWARDSHIP

Despite their differences, cost-benefit analysis and utilitarianism share a common characteristic: Both frameworks are based on a consequentialist approach to social decision-making, according to which public policies should be designed to balance the interests of different members of society. Consequentialism, however, is viewed skeptically by advocates of "deontological" or rights-based ethics. Philosophers such as Locke (1690), Kant (1963), and Rawls (1971), for example, set forth theories in which government actions are justified to the extent that they protect the rights or freedoms of individuals. In debates over long-term environmental management, the notion of *stewardship* offers a distinctive moral outlook that is based on the perceived rights of future generations.

The logic of stewardship is nicely summarized by Thomas Jefferson's aphorism that "the earth belongs in usufruct to the living" (see Ball, 2000). In this perspective, environmental resources are the shared patrimony of present and future generations. While individuals living in today's society hold a *right* to enjoy the benefits provided by environmental systems, they also hold a *duty* to protect and conserve environmental quality for the benefit of future generations. This view is embodied in the definition of "sustainable development" described by the World Commission on Environment and Development (1987, p. 43), according to which natural resources should be managed to meet "the needs of the present without compromising the ability of future generations to meet their own needs."

The moral foundations of the stewardship ethic are explored by Howarth (1997), who argues that a commitment to the principle of equal opportunity between contemporaries implies that present decision-makers hold a duty to ensure that human life opportunities are maintained or improved from generation to generation. At each point in time, parents and their living offspring are contemporaries who are entitled to meaningful equality. In this perspective, actions that conferred short-term benefits but that reduced future opportunities would constitute an unfair use of the power that adults hold in relation to children. Since this position is grounded on an appeal to duties between actual living persons, it is not vulnerable to Parfit's (1983a) argument that the rights of future generations are sharply limited by their hypothetical or contingent status. Part of what present society owes young people, however, is the capacity to provide suitable opportunities to their own children and grandchildren. In this way, direct duties between one generation and the next define a "chain of obligation" (Howarth, 1992) between the present and more distant future generations.

As Page (1983) points out, protecting the life opportunities of future generations requires attention to several factors that provide the basis for achieving a favorable quality of life – natural resources, environmental quality, manufactured capital, social institutions, and technological capacity. In principle, the depletion of one valued asset (such as environmental quality) might be compensated by another (manufactured capital or new technologies) that offered commensurate contributions to human welfare. But in a world of uncertainty regarding the needs and interests of future generations, the only sure way to maintain life opportunities is to pass on a "structured bequest package" (Norton and Toman, 1997) that includes continued access to environmental resources. This point is strengthened by evidence that many people view the substitution of manufactured goods for unique natural environments as morally inappropriate (Sagoff, 1988). In this view, reductions in environmental quality would be permissible only in the face of compelling evidence that future generations would share in the benefits or receive just compensation as judged from their own vantage point (Barry, 1983).

Brown (1998) reasons that the stewardship ethic entails a moral obligation to stabilize global climate as one component of environmental quality. If future generations hold a right to enjoy the benefits of climatic stability, then policies that allowed unrestrained greenhouse gas emissions might inflict uncompensated harms that were morally unjustified. This line of argument conforms to the principal objective of the United Nations Framework Convention on Climate Change, which calls for the "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system." This language is important because the Framework Convention is a binding treaty that has been signed and ratified by 188 nations including the United States.

Although the Framework Convention does not specify the concentration levels that should be considered "dangerous," scientific efforts to support this agreement have explored the prospects for limiting carbon dioxide concentrations to levels no more than 60–260% above the pre-industrial norm (IPCC, 2001c). This range is based on evidence that: (a) small changes in climate would yield relatively modest impacts to which future society could successfully adapt; while (b) large changes in climate would impose a risk of irreversible, catastrophic harms. According to the IPCC (2001c), climate change could produce catastrophic impacts via several plausible mechanisms:

1. The disruption of ocean circulation patterns, which ironically could plunge the European continent into a deep freeze even as the planet as a whole became warmer.
2. The release of greenhouse gases from terrestrial and marine sediments, which could greatly amplify the direct climate change induced by human activities.
3. The possible collapse of the West Antarctic ice sheet, which would lead to a sea-level rise of several meters.

Although none of these scenarios is particularly likely, scientists emphasize that environmental systems are complex, nonlinear, and only partially understood. As a result, it is reasonable to expect "surprises" (Faber *et al.*, 1992) – the occurrence of outcomes that were unforeseen and indeed unforeseeable.

The problem of catastrophic risk is illustrated by an expert opinion survey conducted by Nordhaus (1994a), who asked a group of economists and scientists with expertise on climate change to estimate the probability that a doubling of greenhouse gas concentrations would impose costs equivalent to 25% of world economic output. In Nordhaus' sample, the mean probability estimate was 5%, indicating a significant potential for catastrophic impacts. Since this figure is based on the subjective judgment of technical experts, its scientific reliability is of course limited. On the other hand, this study points to important doubts amongst expert analysts concerning the hypothesis that climate change will have low or acceptable consequences.

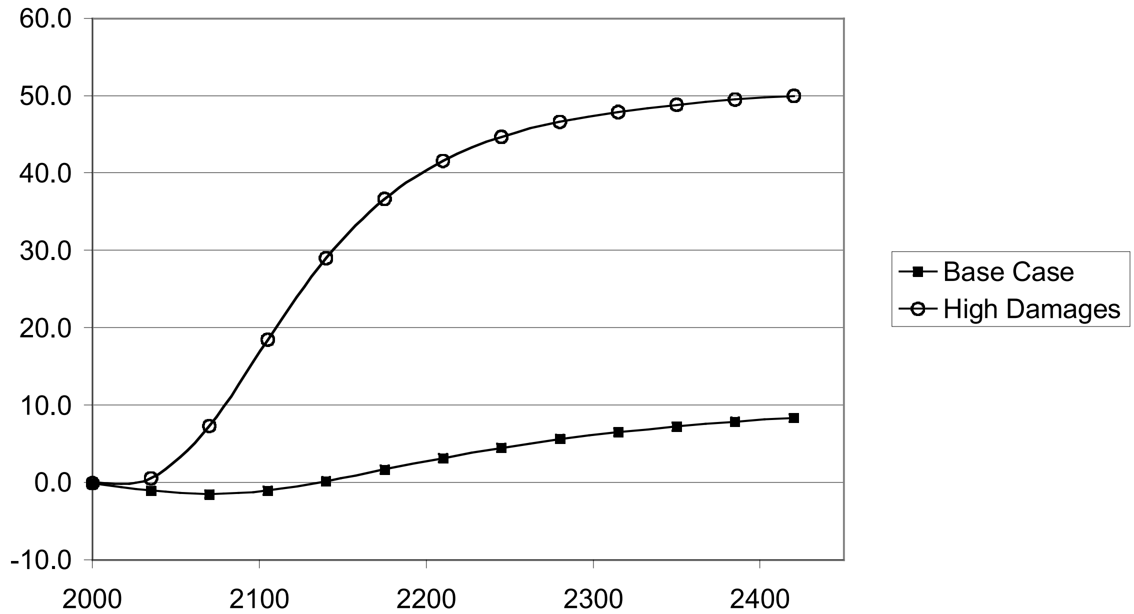
Critics of stewardship and the approach taken by the Framework Convention argue that taking steps to stabilize climate would impose large economic costs that would ultimately harm both present and future generations. In this perspective, high levels of greenhouse gas emissions abatement might reduce the rate of long-term economic growth. Hence both present and future generations might be better off if climate change policies were based on conventional cost-benefit analysis, which aims to achieve an efficient balance between the interests of present and future generations.

This argument, however, is not as clear-cut it as might seem. Consider, for example, the "climate stabilization" scenario depicted in Figures 1-4 in the preceding section of this chapter. In Howarth's (1998) model of climate-economy interactions, greenhouse gas concentrations may be stabilized at a level that is twice the pre-industrial value if emissions are held constant at 6.7 billion tce per year. This goal could be achieved through the use of an emissions tax that rose from $69/tce to $713/tce over the course of the next four centuries. Relative to the business-as-usual (no policy) baseline, this scenario imposes a net cost that rises from $0.1 to $1.5 trillion per year between 2000 and 2070. After 2140, however, the policy yields positive net benefits that rise to a level of $8.3 trillion per year in the long-run future. These long-term benefits are more than twice as large as those that arise when climate change policies are based on the use of conventional cost-benefit analysis. Interestingly, this scenario corresponds closely to the policies that emerge under classical utilitarianism.

Viewed somewhat differently, switching from the climate stabilization scenario to the cost-benefit criterion provides short-term benefits of $0.1 trillion in the year 2000 while imposing uncompensated costs of $4.3 trillion in the year 2420. An advocate of stewardship would view this as an unjustified invasion of the rights of future generations.

There are several points to bear in mind about these calculations. First, the particular stabilization target considered in this analysis – limiting greenhouse gas concentrations to a doubling relative to pre-industrial levels – is in some sense arbitrary. While this target is in the range of possibilities currently under discussion, higher or lower targets might ultimately be justified based on the scientific evidence and policy-makers' considered judgment concerning how much climate change would be "dangerous." Second, these model runs assume that climate change would have negative but relatively modest impacts. In particular, they assume that a doubling of greenhouse gas concentrations would impose costs equivalent to 1.3% of world economic output. While this number is plausible as a central estimate, it does not account for the risk that climate change might impose catastrophic costs. As we saw above, the literature suggests a small but significant probability that climate change would impose damages almost 20 times as large.

Figure 5: Net Benefits of Emissions Stabilization -- Change Relative to BAU (trillion $/year)



To illustrate the importance of this point, Figure 5 depicts the net benefits of the climate stabilization case when the damage coefficient is increased by a factor of 10 – an arbitrary figure that is nonetheless inside the range of plausible possibilities – so that a doubling of greenhouse gas concentrations would impose costs equivalent to 13% of economic output. In this event, net benefits become positive by the middle of the 21st century and rise to a value of $18.4 trillion by the year 2105. In the long-term future, net benefits increase $50 trillion per year. This policy imposes net costs only in the short-term, and those costs are limited to $0.1 trillion per year.

Alternative interpretations of the stewardship ethic are available in the literature. Gerlagh and Keyzer (2001; see also Barnes, 2001), for example, consider a formal model in which polluters must compensate victims for the costs imposed by climate change. In this approach, optimal rates of greenhouse gas emissions control are determined using conventional cost-benefit analysis, which ensures that resources are allocated in a manner that is economically efficient. In this setup, polluters make payments to an intergenerational trust fund that pays compensation to members of future society who bear the costs of climate change. Since the assets held by the trust fund are invested the market rate of return (r), one dollar of environmental costs that occur t years from the present can be financed through an investment of just $1/(1+r)^t$ today. In theory, this approach yields an outcome that both present and future generations would prefer to the case where greenhouse gas concentrations are stabilized in the neighborhood of current levels.

Although the Gerlagh-Keyzer approach is conceptually elegant, it runs up against two types of practical difficulties. First, if the future impacts of climate change are uncertain, then the level of investment required to compensate future generations for climate change damages cannot be operationally defined. This point is highlighted by the comparison of the "base case" and "high damage" scenarios depicted in Figure 5. As Bromley (1989) notes, compensation mechanisms are a problematic means of protecting rights when potential environmental costs are unknown and possibly catastrophic. In such instances, legal systems commonly employ property rules designed to prevent harms before they occur with strict punishments for violations.

Second, the Gerlagh-Keyzer model requires the creation of a financial institution (the trust fund) that would function effectively over the course of many decades or indeed centuries. As Lind (1995) notes, this task would pose daunting practical challenges; it is easy to imagine scenarios in which governments would raid the trust fund to finance short-term expenditures, or in which a financial crisis effectively wiped out the assets held in trust for future generations. Together, these arguments suggest why advocates of stewardship focus on stabilizing greenhouse gas concentrations to protect the rights of posterity.

THE ARGUMENT FROM RISK

In an important sense, the arguments from utilitarianism and stewardship critique the moral foundations of conventional cost-benefit analysis, not the use of high discount rates *per se*. In contrast with these moral critiques, the third line of reasoning explored in this chapter – the argument from risk – accepts the premise that climate change policies should be analyzed based on the private preferences that people reveal through their market behavior. But while conventional discounting procedures rest on the assertion that individuals exhibit a high degree of impatience – and hence an unwillingness to exchange short-term costs for long-term benefits – the argument from risk holds that the use of high discount rates is in fact inconsistent with the empirical evidence.

To understand this point, it is useful to note that financial markets involve the purchase and sale of a large number of assets characterized by varying degrees of risk. Risky assets such as corporate stocks pay average long-run returns of roughly 6% per year in real (inflation-adjusted) terms (IPCC, 1996, ch. 5). As I noted in the introduction, authors such as Nordhaus (1994) and Manne (1995) argue that public policies should be evaluated at a discount rate that reflects the typical returns investors demand on corporate stocks. In this view, the use of low discount rates might lead policy-makers to approve low-return public projects that crowded out private investment that yielded higher returns to society.

Although this claim is intuitive, it runs up against an important body of theory and evidence from the finance literature. In particular, safe forms of investment such as U.S. Treasury Bills generated long-term yields of less than 1% per year between 1926 and 2000 (Ibbotson and Associates, 2001). In financial economics, Treasury Bills are generally viewed as a risk-free asset since their returns are remarkably stable over time. In this respect, they resemble money market accounts and short-term certificates of deposit. By way of comparison, corporate bonds – which are characterized by an intermediate degree of risk – yield long-term returns of roughly 3% per year. In explaining observations of this nature, financial economists work with models in which the expected (or average) rate of return on a risky asset ($\bar{r}_r$) is determined by the return available on safe assets (r_s) plus a risk premium (RP_r) according to the equation:

$$\bar{r}_r = r_s + RP_r \,. \tag{2}$$

Various formulae exist for determining the risk premium investors demand based on the uncertainties that surround the potential returns achieved by a given investment (Cochran, 2001). In general, these formulae are derived from theoretical models in which people allocate investments between available assets to optimally balance the goals of maximizing returns and minimizing risks. These methods agree, however, that the risk premium is positive for investments that increase the degree of uncertainty that surrounds an investor's overall economic welfare. Corporate stocks fall in this category because investors' incomes rise and fall with the market. On the other hand, insurance policies yield payoffs that – although uncertain – serve to reduce the risks that surround an investor's overall financial position. Since insurance policies protect buyers from the risk of incurring large (sometimes catastrophic) losses, people purchase them despite the fact that will (on average) return less cash than money deposited in the bank. In terms of equation (2), this implies that insurance policies have a negative risk premium.

As I noted in the preceding section, climate change policies are designed to reduce the environmental risks faced by future generations. This is illustrated by Figure 5, which shows that climate stabilization can forestall the risk that climate change will impose irreversible, catastrophic costs with a significant (though poorly measured) probability. More formally, Tol (2003) presents a Monte Carlo simulation in which climate change completely devastates the economies of Eastern Europe and the former Soviet Union with a probability of 0.1%. This result occurs because of shifts in precipitation patterns that deprive this region of needed water resources. Less ominous catastrophes occur in Tol's model with greater levels of probability. Tol's study is important because it represents a serious attempt to integrate the scientific, technological, and economic uncertainties that surround global warming using a fully specified mathematical model.

What are the implications of these points for the choice of discount rates in cost-benefit analysis? One approach to answering this question is provided by Sandmo (1972) and Starrett (1989), who explore theoretical models in which public policies should be evaluated using discount rates that reflect the risks those policies impose on future society. According to these authors:

1. If a policy would involve risks that are similar to those posed by private investments, then it would be appropriate to discount its future net benefits based on the returns paid by corporate stocks.
2. If a policy were risk-free, then its net benefits should be discounted at the risk-free rate of return.
3. For policies that provide insurance benefits – i.e., that reduce the overall uncertainties faced by future society – the use of discount rates below the risk-free rate would be theoretically appropriate.

For the reasons described above, it is reasonable to presume that climate stabilization measures fall in this last category.

Alternatively, the general framework employed by Sandmo and Starrett implies that cost-benefit analysts may address questions of risk by: (a) adjusting a standard measure of net benefits to account for the value of risk reduction; and (b) discounting adjusted net benefits at the risk-free rate of return (see Howarth, 2003). This approach is illustrated by Cline's (1992) analysis of the costs and benefits of climate change, which supports stabilizing greenhouse gas emissions at roughly half the year 2000 level under business-as-usual – a target that is even stricter than the climate stabilization scenario described above. Although Cline defends his use of a 1.3% annual discount rate based on utilitarian moral reasoning, this discount is in line with the rates of return paid by safe investments.

It is important to note that this "argument from risk" does not assert that policy-makers should adopt *ad hoc* or ethically-based discount rates that are below the returns paid by private-sector investments. Instead, the point is that climate change policies have risk characteristics that are quite unlike those pertaining to corporate stocks. According to economic theory, the choice of discount rates should reflect the risk characteristics of the policy or project under examination. The use of low discount rates is appropriate when evaluating policies that reduce risk.

SUMMARY AND CONCLUSIONS

The economics of climate change emphasizes an approach in which the future benefits of greenhouse gas emissions reduction are discounted at a rate equal to the long-run return on corporate stocks. Since stocks generate real (inflation-adjusted) returns of roughly 6% per year, and since a 6% discount rate implies that one dollar of benefits obtained one century from the present attains a present value of less than one cent, this method implies that only modest steps towards greenhouse gas emissions are economically warranted.

This chapter has critiqued this approach through appeals to three independent lines of reasoning. *First*, a classical utilitarian would reject conventional discounting in favor of an approach that attached equal weight to the welfare of present and future generations. Because the prospect of economic growth implies that the utility provided by an extra dollar of expenditure should fall over time, classical utilitarianism is possibly consistent with the use of a low (but positive) monetary discount rate. Nonetheless, a utilitarian would view the use of a 6% discount rate of morally unfair.

Second, the concept of stewardship, which asserts that future generations are entitled to enjoy the benefits of an undiminished natural environment, implies that it is morally unjust for present generations to engage in actions that impose uncompensated environmental costs on posterity. Yet the use of conventional discount rates gives rise to an “optimum” in which greenhouse gas emissions impose major costs on future generations, including a real potential for low-probability, catastrophic impacts.

Third, the use of a 6% discount rate is appropriate in the analysis of public policies that have risk characteristics that are similar to those associated with corporate stocks. Economic theory, however, suggests that discount rates of 1% or less should be used to evaluate policies that reduce future risks. Of course, a main objective of climate change policies is to reduce the risks faced by future society.

Significantly, these arguments rest on quite different judgments concerning the principles that should be employed in balancing the interests of present and future generations. All three, however, suggest that there are good reasons to stabilize greenhouse gas emissions significantly below the level current generated by human activities. One would need to reject each of these arguments to justify the use of conventional discounting procedures in the economics of climate change.

APPENDIX: MODEL DESCRIPTION[1]

The numerical results described in Figures 1-5 are based on a simplified model of the links between climate change and the world economy that was developed by Howarth (1998). The model's empirical assumptions are derived from the previous work of Nordhaus (1994b), who provides a concise representation of climate dynamics and the technical determinants of economic growth. Nordhaus' analysis, however, focuses on an "optimal growth" model in which decisions concerning consumption, investment, and greenhouse gas emissions are made by a hypothetical central planner to maximize a measure of long-term social welfare. Howarth's model, in contrast, makes use of an alternative specification in which routine economic decisions are made by individual households and businesses. In this model, the role of government is limited to the definition of environmental policies.

The model considers a market economy in which goods and services are produced using inputs of capital and labor. Economic output is divided between consumption and investment, and production is carried out by competitive firms that seek to maximize their profits given the prevailing prices of inputs and outputs. In the model, wages and salaries account for three quarters of the value of economic output while capital accounts for the remainder. In addition, the model assumes that technological change augments the level of output an initial rate of 1.4% per year. In line with standard demographic projections, human population rises from its present level of about 6.0 billion persons to 10.5 billion in the long-run future. Population growth is concentrated in next one hundred years, during which four-fifths of the total increase occurs. The model assumes that the supply of labor is proportional to total population. Individuals earn wage income by providing labor services to employers in the production sector.

[1] This Appendix is adapted from Howarth (2000).

Decisions concerning savings and investment are made by private individuals. A typical person lives for seventy years, investing part of her income in youth to finance increased consumption in old age. Savings are invested in capital goods at the prevailing interest rate, which reflects the incremental contribution that increased wealth makes to future economic activity. The model's assumptions about consumer preferences are chosen to match expected rates of economic growth.

The model assumes that greenhouse gas emissions – which include carbon dioxide, chlorofluorocarbons (CFCs), and CFC substitutes – increase in proportion to economic output. In the absence of emissions abatement policies, emissions in the year 2000 amount to some 0.37 kg of carbon equivalent per dollar of output. Due to technological innovation, the ratio of emissions per unit output falls at an initial rate of 0.55% per year. The model assumes that emissions abatement, although technologically feasible, is economically costly. A 50% reduction in greenhouse emissions requires a 0.93% reduction in economic output. Abatement costs rise to 6.86% of economic activity when emissions are fully controlled.

The model rests on a simple, but analytically tractable, representation of climate dynamics. Approximately two-thirds of greenhouse gas emissions go into the atmosphere, while the remaining third is absorbed by the biota and the surface waters of the oceans. Once in the atmosphere, a typical greenhouse gas molecule remains airborne for 120 years. Thus anthropogenic emissions of greenhouse gases are removed from the atmosphere to the deep ocean at an effective rate of 0.833% per year. The model assumes that mean global temperature increases with the level of total greenhouse gas concentrations, measured in terms of carbon equivalent. A doubling of greenhouse gas concentrations relative to the pre-industrial norm (i.e., the prevailing conditions of the late 19th century) causes a net temperature increase of 2.91 ºC.

The climate impacts of methane and nitrous oxide (which are small in comparison with those caused by carbon dioxide and halocarbons) follows a fixed time path that is not affected by public policies.

A critical aspect of the model concerns its assumptions concerning the damages imposed by climate change. Following Nordhaus (1994b), the model assumes that a 3.0ºC temperature increase imposes environmental costs equivalent to a 1.33% reduction in economic output, while a 6.0ºC temperature increases leads to a 5.32% output loss. The level of damages is proportional to economic activity.

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