Integrated Assessments of Climate Change Policy: Intergenerational Equity and Discounting

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1. Introduction

The effective discount rate is one of the most sensitive parameters in integrated climate-economy assessments. The appropriate technique and the choice of the 'correct' discount rate is the subject of a major debate. The central issue is whether the special characteristics of the global warming problem like the very long time horizons, the possibility of irreversible changes, the threat of potential climate catastrophes and others would justify an exceptional treatment among the many issues on the current public policy agenda. Setting the discount rate to ethically pleasing low levels would not only be economically ungrounded, but it would also make the cost and benefit calculations related to the various abatement and adaptation strategies incompatible and thus incomparable with a long list of other environmental and social policy issues that also demand immediate attention and action.

More than a decade ago, a study by Resources for the Future produced a standard setting study on the discounting issue (Lind, 1982). These results have been subsequently revised in light of new theoretical research and empirical evidence. Lind (1995) revisits the discounting problem in the context of global warming. This contribution marks a turning point in the discounting debate as he seems to abandon the consumption equivalent technique for both conceptual and practical reasons.

The discounting problem is at the heart of any intertemporal decisions. Consequently, it also plays a central role in models of economic growth. Alan Manne (1995) points out that setting an arbitrary discount rate without destructing the consistency of the overall modeling framework would imply unrealistically high investment rates until the accelerated capital accumulation would drive down the marginal productivity of capital to a level consistent with the plugged-in discount rate. This implies that the lower discount rate would not necessarily result in lower carbon emissions, but may produce other undesirable environmental impacts.

One important assumption behind Manne's simple model is a single immortal agent who controls all decisions about production and consumption, as well as savings and investments. Eternity is, of course, an unrealistic assumption for an individual, but it provides a meaningful representation of long-lived organizations. In contrast, Schelling (1995) presents arguments of why the concept of time preference is irrelevant in the context of such long-term issues like global warming. His reasoning is based on the concerns of a benevolent individual and may not necessarily coincide with the assignments of a guardian of long-term public interest like, for example, a trust fund manager.

This paper explores new argument and new developments in the debate on discounting, the ‘correct’ techniques and rates, and, as it is sometimes inevitable, looks at the broader question of the applicability of cost-benefit analysis to long-term environmental issues like climate change.

2. Discounting techniques

When we attempt to identify the underlying techniques and conceptual backgrounds of the specific discount rates used in different climate-economy models, we find two basic approaches and a number of variations. The first approach is rooted in the ideal world of optimal growth models with no distortions, while the other approach attempts to alleviate the conceptual and technical difficulties resulting from the presence of distortionary taxes in the economy.

A convenient starting point to explain how the effective discount rate is derived for the various models is a simple optimal growth model as formulated by Ramsey (1928) and explained in some detail by Manne (1995) and Nordhaus (1994). Our discussion here is based on Solow (1970). The optimality criterion for the growth path is to maximize the social value of the future consumption stream by discounting all future utility back to the present using a social rate of time preference and computing the sum of these discounted utilities over an infinite time horizon. For the continuous case (Solow, 1970:82), the problem is to maximize:

$$W = \int_{0}^{\infty} e^{-(a-n)t} \; U(c)dt \qquad (1)$$

where W is the social value of the consumption stream, a is the rate of social time preference, n is the rate of population growth, and c is per capita consumption. Solow identifies the necessary condition for optimality as:

$$\frac{d/dt\,(U')}{U'} = -\{\, r^*(t) - a \,\} \qquad (2)$$

where $r^*(t)$ is the marginal productivity of capital at time t along the optimal path and, given the assumption of competitive markets, it is equal to the instantaneous real interest rate. Thus, the optimality criterion states that the social marginal utility of per capita consumption is declining at the rate given by the difference between the marginal productivity of capital and the social rate of time preference. By differentiating Equation (2), Solow derives:

$$\frac{U''(c^*)dc^*/dt}{U'(c^*)} = \frac{c^*U''(c^*)}{U'(c^*)}\frac{1}{c^*}\frac{dc^*}{dt} = -j\frac{(c^*)}{c^*} = -(r^* - a) \qquad (3)$$

where j is minus the elasticity of the social marginal utility of per capita consumption. Under steady-state conditions, Solow then takes f as the rate of labor-augmenting technical progress, that is, the steady-state rate of growth of output and consumption per capita. Thus along the optimal steady state path, it must hold that:

$$r^* = a + jf \qquad (4)$$

To summarize: in the optimal growth framework, the real interest rate is equal to the discount rate on goods and services, and is derived from three factors: time discounting (a) (this is $\tilde{n}$ in both Alan Manne's (1995) discussion and in the DICE documentation (Nordhaus, 1994), the elasticity of the marginal utility of consumption (j here, v in Alan Manne's paper and $\acute{a}$ in the Nordhaus analysis), and the growth in consumption (f) (g in both the Manne and Nordhaus papers).

In this model of an ideal world, the social rate of time preference (observed from the consumption rate of interest) and the opportunity cost of private capital (observed from the marginal rate of return on private investment) are equal and they are both equal to the market rate of interest. Once the assumptions about ideal conditions are abandoned, however, the social rate of time preference and the marginal rate of return on private investments diverge due to market imperfections, notably corporate profit tax and personal income tax.

Searching for the appropriate discount rate in a world with distortionary taxes, Lind (1982) developed what was the dominant discounting technique for cost-benefit analyses throughout the 1980s. Lind first established an analytical framework to separate the issues of time preference and the opportunity cost of public investments. He argued that the social rate of discount should be equal to the social rate of time preference as determined by the consumption rate of interest. The basis for its numerical estimation are the returns on market instruments that are available to investors. The effects on private capital formation should be accounted for by using a conversion technique and the concept of the 'shadow price' of capital. This latter represents 'the present value of the future stream of consumption benefits associated with $1 of private investment discounted at the social rate of time preference' (1982:39). In this way, effects on capital formation are converted to their consumption equivalents through the use of the shadow price of capital. Finally, a single rate of discount, the consumer's rate of interest, is applied to the benefit and cost streams.

A practical difficulty of the 'shadow price of capital' approach is that to compute it one needs to know the marginal rate of return on private capital, the marginal rate of taxation on capital income, rates of depreciation and reinvestment, the consumer's rate of interest, and the marginal propensity to save. Nordhaus concluded that while the Lind approach is extremely useful and elegant in consolidating capital-market distortions, it is impossible to apply (Nordhaus, 1994, personal communication). The practical obstacle arises from the need to account for all flows in and out of consumption and investment, which requires a much deeper understanding of their governing forces than is currently the case.

It is obvious that the Ramsey-based discounting is a special case of the consumption-equivalent technique. In the absence of distortions, all shadow prices are equal to one, so there is no need to convert expenditures into consumption equivalents before a uniform discount rate can be applied.

In his amendment of the consumption-equivalent technique, Lind revisited the government's discount rate policy for public projects in light of new observations on international capital mobility, the effects of financing government deficit on crowding out private investments, and in behavioral economics on the individual's rate of time preference (Lind, 1990). His most important conclusion relevant to the problem of climate change (and long-term policies in general) is that intergenerational resource allocations should be based either on a utility function over time or on some other decision rule incorporating intergenerational equity. Lacking these, however, the government's long-term borrowing rate should be used in evaluating the effects of projects involving long-run intergenerational resource allocations.

The global warming problem added a new impetus to the discounting debate. Broome, for example, devoted almost half of his book on the costs of global warming to the problem of discounting (Broome, 1992). His starting point was that the real problem is discounting future well-being and that discounting of commodities is just a practical short-cut to discounting well-being. If and when it works, appropriate discount rates for commodities can be derived from the markets: the consumer interest rate or the producer interest rate might offer good starting points. However, Broome presents a long list of arguments why the short-cuts are inadequate in the context of global warming. The consumer interest rate is not appropriate because future generations are not present in the market, therefore the consumer rate of interest does not include the effects of their preferences and thus the value of future commodities. The producer rate of interest is not appropriate either because the production of commodities involves GHG emissions and other environmental damages and these negative externalities are not included in the producer interest rate, which therefore does not represent the true opportunity cost of commodities. Given all these difficulties involved in the short-cuts, one needs to address the problem of discounting future well-being directly. Broome's solution to the problem is the use of a zero discount rate.

3. Discount rates

Toth (1995) evaluated a set of integrated assessments that have been developed to analyze cost-benefit relationships of various climate policies - ranging from inaction to drastic GHG abatement measures - is presented in Table 1. Here we are primarily interested in the relationships between the effective discount rate and the shadow value of carbon emissions along the optimal path.

Table 1: Discount rates and implications

Model	Discount rate[a] (%)	a	j	f	Shadow value[b] ($/tC)
Integrated benefit-cost analyses					
DICE	6	3	1	3	5.3 → 10.0
	6	1	2	3	10.1
	6	0.1	2.5	3	10.3
CETA	5	3	1	2	11 → 20
PAGE	5				20 (5-40)
Fankhauser	‘1.5-6’	0.5 ‘0-3’	1	2	20 → 27 (mean)
	5	3	1	2	5.5
	2	0	1	2	48.8
Cline	1.5	0	1.5	1	q=0.74-4.18
	3	0			q=0.44-1.71
	5	0			q=0.33-1.12
Cost-effective analysis					
G2100	5	3	1	2	{0-208}

[a] Effective discount rate or marginal productivity of capital;
[b] Shadow value of carbon emissions along the optimal path or marginal social cost of emissions.

DICE

The pioneering work in the field of climate economics has been that of Nordhaus (see e.g. Nordhaus and Yohe, 1983). His efforts include DICE, the Dynamic Integrated model of Climate and the Economy (Nordhaus, 1992; 1994). This is probably the best starting point because it is well known, marvelously documented, transparent, and easily accessible. Moreover, it has often been used as a benchmark or reference point in other studies.

Given the extremely long time lags between GHG emissions and their economic impacts, the concept and models of optimal growth offer a convenient framework for analysis. Nordhaus took the model version formulated by Frank Ramsey in 1928 and extended it to include both the impacts of anthropogenic climate change and the allocation of resources to reduce the emissions that induce it. The optimization criterion in DICE is to maximize the discounted sum of the utility of per capita consumption, that is, the value of a traditional social welfare function. Paths of optimal growth affected by climate change or a mitigation policy are diverted from the unconstrained optimal path as a result of losses in output due to global warming and the diversion of resources to reduce emissions. Output is computed from a standard, constant-return-to-scale Cobb-Douglas production function. Together with the output of goods and services, GHG emissions are also generated according to a slowly declining emissions/output ratio.

A small set of equations traces the fate of GHG emissions in the atmosphere. First, their accumulation and transportation are determined. Total radiative forcing and climate dynamics are calculated using a simple, three-layer reduced-form coupled atmosphere-ocean model. The resulting globally and seasonally averaged temperature change drives a quadratic damage function to feed back climate impacts to the production function.

In the DICE model, utility discounting is included in the objective function. Future utility flows are discounted at the pure rate of social time preference (*a* in Table 1) of 3%. Combined with the elasticity parameter (*j* in Table 1) of 1 that follows from the logarithmic utility function and a growth rate (*f*) of 3%, the effective discount rate in DICE is 6%. This, together with all the other 'best-guess' values for the various model parameters, provides a carbon tax equivalent on GHGs along the optimal path starting at US$(1990) 5.3 per ton of carbon.

An important point in the DICE analysis and, in fact, in all optimal growth models is that if societies were to decide to be less impatient and to reduce the pure rate of social time preference (*a*) to a low level like 0.1 and the economy was still growing, then the implications for the shadow value of carbon emissions would not necessarily show dramatic increases. For the period 1995-2025, the US$ 5.3-10 per ton C values for the central case solution would change to marginally higher values.

CETA

A cost-benefit model developed by Peck and Teisberg (1992; 1994) has been used in various studies to explore the relationship between the value of information about impacts and damages and the optimal time path for emission controls. The authors investigate the sensitivity of optimal carbon control strategies to parameters of their Carbon Emission Trajectory Assessment (CETA) model (1992). The model has five modules. Emissions projections and cost calculations are based on the Global 2100 model (Manne and Richels, 1992). Impact and damage assessments are treated similarly to DICE (see above).

CETA is then used in a simple decision tree framework to estimate the value of information about global warming uncertainties. The results of Peck and Teisberg suggest that if an optimal control policy is used under uncertainty, the eventual resolution of uncertainty has a high value relative to current research budgets, and resolving uncertainty about the costs of warming is nearly as important as resolving uncertainty about the extent of warming. In addition, the CETA calculations show that the benefits associated with the immediate resolution of uncertainty would not be much higher than if it were resolved within the next two decades. This implies that some time is available to plan and execute a carefully designed research program. In contrast, the CETA results suggest that if the real world political process were to result in a suboptimal control policy being chosen under uncertainty, and this poor choice could have been prevented by the early resolution of uncertainty, then the benefit of early resolution would have been significantly higher.

The CETA model uses an effective discount rate of 5%. Calculated shadow values range from US$(1990) 11 to 20 per ton of carbon. These higher shadow value figures, compared to those in DICE, however, are only partially due to the slightly lower initial discount rate (5% compared to 6% in DICE). Rather, they are due to the larger size of damage calculated in CETA. In DICE, damage is directly proportional to income, whereas in CETA damage is proportional to the size of the labor force (expressed in efficiency units). It is also worth noting that the case presented here is only one of many cases investigated by Peck and

Teisberg. Their analysis is famous for providing insights into the sensitivity of the shadow value of carbon emissions with respect to different assumptions on the level and exponent of the damage function.

PAGE

Another example of a fully integrated climate-economy model is PAGE, the model for Policy Analysis of the Greenhouse Effect (Hope et al, 1993). It is a probabilistic model that includes a simple representation of all important elements of climate change, from emission policies and control costs to impact mitigation strategies and damages. To demonstrate the effects of individual perceptions of the global warming problem, the model uses multi-attribute utility functions. The PAGE model covers the globe and divides it into four major regions: the European Community (EC), the rest of the OECD, Eastern Europe and the former Soviet Union, and the rest of the world. The model's time horizon covers the period 1990-2100. In addition to CO_2, other major GHGs are also included, notably CH_4, CFCs, and HCFCs.

An individual model run starts with specifying a preventive (GHG abatement) and an adaptive (impact mitigation) strategy by the user. Emission control policies (or the lack of them) affect global temperature change and generate prevention costs. Adaptive policies (if applied) comprise the second part of the total estimated costs. Non-monetizable environmental and social impacts are included in the model as a multiplier of the total economic impacts in a computation to show how high they would need to be in order to justify adoption of the prespecified policies. The PAGE model uses a uniform discount rate of 5%. The shadow values of GHG emissions calculated under various parameter constellations range from US$ 5 to 40 per ton of C equivalent.

Fankhauser

The objective of the Stochastic Greenhouse Damage Model is to provide an order of magnitude assessment of the social costs (the shadow value) of GHG emissions (Fankhauser, 1994). This is implemented in the context of a stochastic model where uncertain factors are defined as random variables. This is the opposite of what optimization models do where marginal costs are determined by the intersect with the damage function. In this model, the marginal costs are calculated at the emissions level actually observed. Their best-guess figures are taken together with a distribution of future emissions that is unknown. Therefore, as Fankhauser notes, the numbers presented in the shadow value column of Table 1 for the Stochastic Greenhouse Damage Model give little indication of the socially optimal carbon tax. These results are more relevant for individual abatement projects if the world were to follow the optimal path.

In terms of discounting, Fankhauser follows Lind's consumption-equivalent technique: all investment effects are converted to consumption equivalents using a shadow price of capital and then the social rate of time preference is used for discounting. The relatively low discount rates by Fankhauser's stochastic base case do not lead to overwhelmingly high shadow values where the means range from US$ 20 to 27 per ton C.

It is interesting to observe that when Fankhauser uses an effective discount rate (5%) closer to Nordhaus's value (6%), his calculated shadow values (US$ 5.5 per ton C) get very close to the initial optimum path value from DICE (US$ 5.3 per ton C). Yet, we must bear in mind that the ways these numbers have been derived as well as their interpretations are quite different.

Cline

One of the first attempts to bring together a diverse set of benefit and cost assessments into a consistent cost-benefit framework was made by Cline (1992). The large differences in the amount and quality of data sources to estimate the two terms of the cost-benefit ratio reflect the imbalances in the number of studies and reliability of results of the then available global warming studies: a small number of impact and damage assessments conducted mainly in Europe and North America to estimate benefits, versus a diverse set of global energy-economy models to calculate costs.

Cline identified 16 damage categories. He surveyed several studies conducted in the potential impact areas largely independently of each other to make his own damage estimates for each category. Most studies, however, were conducted in the United States or in other developed market economies where climate sensitivity is lower and capacities for adaptation are higher than in less developed countries. Extrapolation is difficult, but is the only plausible solution to generate global estimates.

Another problem is that of the temporal dynamics. Trying to extract the maximum amount of information from the then available material, Cline made estimates for two comparative static scenarios: the usual $2\times CO_2$ equivalent equilibrium warming (assumed to be 2.5°C) and what he called ‘very-long-term warming’ (taken to be 10°C associated with an $8\times CO_2$ equivalent level of GHG concentrations and to be reached by the year 2275).

Due to the large number of source studies and the large diversity of assumptions behind them, it is a major task to make them compatible and to derive damage estimates that fit together. Despite the slight tendency to overestimate the impacts of climate change in many of the source assessment studies, Cline’s aggregate estimates were very close to those turned up by other studies (Nordhaus, 1991; Fankhauser, 1993).

On the cost side, the availability of consistent and well-documented modeling results provides a more promising starting point. Nevertheless, global energy models differ significantly in their basic socioeconomic and technological assumptions, energy sector detail, time horizons, and regional and temporal resolution. This makes the selection of a single study as a representative of some kind of consensus clearly impossible. Cline conducted an in-depth survey of six state-of-the-art global energy-economy models and developed a synthesis based on their results.

Damage assessments and cost estimates are then synthesized in a cost-benefit model that incorporates other aspects of climate policy, such as the costs of reduced deforestation and increased afforestation. The final results are presented as 36 combinations of the four key parameters: the social rate of time preference, the climate sensitivity factor, the exponent of the damage function, and the base value of the damage function.

Cline also uses Lind’s consumption-equivalent technique as a starting point for his discussion of the appropriate rate and technique of discounting. There are, however, two important distinctive features. First, Cline argues on ethical grounds for an $a = 0$ (zero rate of pure time preference) as an appropriate value to use for intergenerational problems. Second, he contends that growth discounting (which is associated with the declining marginal utility as income rises) is the social rate of time preference in his benefit/cost framework and it is already and directly included in the utility function.

Cline’s conclusion from his cost-benefit analysis is that the ‘benefits of an aggressive program of abatement warrant the costs of reducing the GHG emissions if policy-makers are risk averse, or if one is pessimistic and concentrates on high-damage cases’ (Cline, 1992:311). In particular, a combination of low discount rate and high damage is necessary to justify undertaking significant abatement action.

Global 2100

The final example, the Global 2100 model, is not an integrated model but is included in Table 1 to provide a comparison between integrated assessments and an earlier cost effectiveness study. (In fact, it has also become part of an integrated model by now Manne et al, 1995).) The Global 2100 model itself has been through many changes and modifications over the past few years. Here, we refer to the version as presented by Manne and Richels (1992). The model disaggregates the world into five geopolitical regions: the United States, the rest of the OECD, the former Soviet Union, China, and the rest of the world. For each region, relationships between the energy sector and the rest of the economy are modeled by combining two models: ETA (an energy technology process model) and MACRO (an aggregated production function quantifying the substitution relationships between capital, labor, and energy inputs). Regional models can be linked in various ways, most typically through the international crude oil market and, for the purposes of analyzing various carbon emission abatement strategies, through an international market of carbon emission permits.

In the Global 2100 model, the macroeconomic assumptions follow the optimal growth tradition as far as discounting is concerned. They provide an effective discount rate of 5%. The carbon tax depends on the policy and the scenario specified. For the 20% carbon emissions reduction scenario, for example, the carbon tax starts at zero and rises to US$ 208 which is basically the equilibrium value for the long-run backstop technology.

4. Modeling the long-term: ILA versus OLG

Two model types represent two extremes of formulating intertemporal optimization problems. The first one is behind the Ramsey-type of optimal growth models. It takes the perspectives of a single, infinite-lived agent (ILA) acting through his savings/investment decisions as a trustee on behalf of both the present and future generations. Many authors have criticized this representation for various reasons and suggested that it might be the reason why, in their view, optimal climate policies discriminate future generations. The bequest motive, central to the ILA paradigm, disappears if endowments and allocation decisions made by subsequent generations are modeled independently but in a unified framework depicting several generations in different segments of their life cycle but living simultaneously, that is in overlapping generations models (OLGs). In OLGs, each generation saves in their active years and dissave in retirement. The question is whether this formulation provides more pleasing results than ILA-based models. Not surprisingly, opinions differ widely.

Bayer and Cansier (1998) also reject the Ramsey model and propose their own OLG model to study implications of different approaches to discounting for long-term environmental and resource policies and sustainability. They combine their OLG model with Lind's consumption equivalent technique of discounting (largely following Cline, 1992) with a twist: intragenerational shadow prices of capital, they take the sum of time and growth discount rate, while for evaluating consumption effects on future generations, only growth discounting is used.

This adds further complications to the already notable problems of the consumption-equivalent technique (see elsewhere in this paper).

The trouble with both of the above models are that their OLG formulation does not fit the analytical requirements of the GHG problem. Stephan et al. (1997) present a thoughtful comparison of two, comparable models: one formulated from the ILA perspective, the other an OLG model. They observe that, since expenditures for climate policy constitute a straightforward alternative to physical capital formation and each generation has stakes in reducing future losses due to climate change. Stephan et al. show that if model assumptions are harmonized in a plausible range, results from the ILA and OLG models are sufficiently close to each other so that they can be treated equally in terms of the policy relevance of the insights they provide.

Manne (1996) arrives at similar conclusions by linking an OLG-based intertemporal equilibrium model to a reduced-form version of the MERGE model. Experiments conducted with this instruments demonstrate the feasibility of adopting a completely descriptive OLG approach to the climate problem. Similarly to ILA models, utility discount rates play an important role in OLGs as well. Unrealistically low (high) values would lead to implausibly high (low) rates of investments in the near term. Finally, Manne finds that, under comparable assumptions and parameterization, the OLG model does not provide much in terms of additional insights into climate policy.

5. Can we stimulate efficient climate policy by manipulating the discount rate?

Nordhaus (1996, 1997) performs a systematic analysis with his DICE model in order to assess the relative merits of various proposals to twist the discount rate with respect to leading to efficient climate policy proposals. Efficiency is measured by comparing costs and associated climate benefits to those of policy proposals derived from environmental targets like stabilizing emissions, concentrations, or climate itself. Nordhaus's results appear to be rather powerful: introducing artificially low discount rates across the board or preferential (low) discount rates for environment/climate-related assets lead to policies whose efficiencies remain far behind those that concentrate on the environmental target itself and seek cost-effective implementation. Moreover, whether to reject the applicability of cost-benefit criteria depends on the nature of the problem rather than on what results emerge from analyses with fudged discount rates.

Tol (1998a) uses his FUND model to study policy implications of using different discounting techniques and the resulting different discount rates. Specifically, he contrasts what he calls classic discounting (the traditional PRTP-based approach) at different rates with Heal's (1997) logarithmically declining discount factor, with Rabl's (1996) discounting approach in which the discount rate drops to zero at a predetermined time in the future, and with Chichilnisky's (1996) intertemporal welfare function which explicitly attempts to include sustainability criteria, although the latter is difficult to relate to non-trivial climate change targets.

It is obvious that discounting according to Heal and Rabl are essentially equivalent to manipulating the discounting rate in traditional discounting, i.e., prescribing ethically pleasing but unrealistically low discount rates. In contrast, Chichilnisky's sustainability criterion is implemented as an externally defined CO2 concentration target. Tol's analysis with FUND reconfirms Nordhaus's results with DICE: tinkering with the discount rate results very poor climate-policy proposals in terms of economic efficiency. Marrying the "sustainability target" with the welfare optimization framework was less successful as it apparently led to an overdetermined specification and the model was unable to reconcile the externally prescribed sustainability target with what its own welfare-dependent target and, therefore, produced partly counterintuitive results.

An interesting by-product of what originally may have been intended as a sensitivity study of impacts of different approaches to discounting on optimal climate policy is the insight into the implications of international cooperation. Not only are optimal emission levels lower in the absence of cooperation for each discounting case studied, but 2100 concentration for the highest cooperative case (classic discounting at 3 percent) is more than 10 percent below the lowest non-cooperative concentration (using Heal discounting at 1 percent). The numbers should not be taken too seriously but the insight is clear: realistic prospects for an effective and sustainable climate-policy regime would foster more significant emissions reductions globally than pursuing ambitious pioneering based on manipulated discount rates.

These exercises show that none of the proposals to tilt the discount rate in order to favor future generations leads to efficient policies. This raises the question: what are the criteria for abandoning CBA results as the prime source of policy guidance and look for absolute environmental targets? Suppose a major environmental disaster in the distant future with catastrophic damages. CBA conducted from the perspective of present-day generations with standard discounting would raise little concern due to the power of discounting. However, as time goes by, the disaster would get closer to future generations of decision makers and would increasingly factor into their cost-benefit balance. If the disaster involves a natural system with long lead times and inertia that make avoiding it physically impossible, there is good reason for taking this event as threshold that should not be crossed. Defining this threshold as an environmental target would then be subject of a cost-effectiveness analysis.

Increasing attention has been paid to a series of potential geophysical discontinuities in which crossing an assumed threshold in anthropogenic climate forcing, the qualitative behavior of the underlying system would change with major consequences for climatic patters of regions at continental or hemispheric scales. The collapse of the North-Atlantic deep water formation (dubbed as the conveyor belt) is one example (see Rahmstorf, 1996, 1997; Stocker and Schmittner, 1997 for the geophysical details; and Toth et al., 1998 for an analysis of the associated global climate target and permitted emission corridor).

Nevertheless, target-oriented cost-effectiveness analysis have their potential pitfalls as well. These particularly affect intergenerational equity when elements of a policy portfolio contain elements with widely differing costs that are interrelated and change over time.

Tol (1998b) looks at the implications of the least-cost strategy to stabilize GHG concentrations by considering the effects of alternative assumptions about technological development on the time paths of marginal abatement costs, the associated temporal patterns of emission reductions and costs. Tol constructs a simple model that prescribes a baseline emission path, an externally defined ceiling for cumulative emissions and depicts assumptions about costs and benefits of research and development to foster decarbonization. Under some simple but plausible assumptions about R&D and technological learning-by-doing, the model supports the validity of earlier insights gained from other models that it is more efficient to increase the share of R&D activities at the expense of immediate drastic reduction in current climate policy portfolios, at least from the perspective of a single, long-lived decision maker. This very assumption is then looked at more closely by Tol with a view to its plausibility (future policymakers sticking to a predefined concentration target, although it is inefficient according to their own cost-benefit ratio) and its implications as a potential conflict between collective (semi)rationality of intertemporal cost-effectiveness and the individual rationality of each generations' decision makers.

While it is not surprising that a positive PRTP (effective discount rate exceeding growth rate in the context of this analysis) increases the burden of later generations and thus might hurt the principle of intergenerational equity, it is less reassuring that the rationality of the optimal path for later generations might suffer. Tol shows that simply setting the PRTP=0 does not solve the problem. As a remedy, he proposes the non-envy principle to step beyond the pure efficiency framing and to give more weight to concerns over intergenerational equity. This implies that costs of GHG reductions are distributed equally (relative to income) across generations. The climate policy portfolios of different generations would still differ but their relative costs (as fractions of income) would remain the same. Under these assumptions, Tol calculates higher near-term expenditures for climate protection but the importance of R&D in the portfolio remains high.

Tol's analysis reconfirms earlier insights about the cost-effective intertemporal allocation of GHG emission reduction efforts and adds valuable observations about the implications of alternative assumptions about the relationship between timing, costs and benefits of technological R&D. While these results are robust even in the partial equilibrium framework, it is more difficult to judge the validity of results on intertemporal equity. In reality, climate policy outlays compete with current consumption and investment expenditures, future growth rates and thus income levels are affected by the amount of funds diverted from investments in the near-term. Nevertheless, it would be most valuable to test the implications of the non-envy principle with a full-fledged intertemporal optimization model that involves the production side, investments, and capital formation as well.

6. Closing remarks

Returning to the central question of this paper: are techniques of CBA applicable to the climate change problem at all? And if so, what should be the appropriate discount rate to compare costs and benefits over time? To what extent should their results guide policy? Three major lines of thought have emerged in the debate over the past few years.

The first one maintains that the very nature of these long-term issues is that impacts (i.e. benefits) will come decades later. This leaves ample time to revisit the issue regularly in the future. The implication is that traditional off-the-shelf CBA is appropriate for policy analysis even in this case. The discounting technique and the discount rate should therefore be the same as for any other public policy issue. Regular re-assessment of the problem will make sure that policy-makers will recognize the problem in due course and revise policies accordingly.

The second line of thought recognizes that the technique of CBA is appropriate to address climate policy but tries to bring distant economic losses due to global warming closer to the attention of present-day decision-makers. The proposed way to implement this objective is to use lower discount rates for valuing faraway future impacts. There is increasing evidence (e.g., Nordhaus, 1996), however, that fudging the discount rate does not help either to save ecological treasures in the distant future or to achieve efficient abatement policy.

Representatives of the third group maintain that if there are hard to value assets or highly valued environmental components at risk and/or the inertia of the underlying biogeophysical system is such that there is a severe danger of going beyond a point-of-no-return than the cost benefit argument has only limited validity. The best and economically most efficient strategy in this case is to define long-term environmental goals and work out the optimal cost-effective policy to reach them.

The present author has been arguing in line with this third approach (Toth, 1993). CBA is nevertheless an important source of information. Keeping in mind all their drawbacks and deficiencies, cost-benefit ratios for climate change (both the damage function and the WTP kind) are useful to compare with cost-benefit indices derived for other environmental issues and social policy problems. Cost-benefit ratios, however, should not be the sole base of social decisions. Analysts have the responsibility to help policymakers and other social actors define their long-term environmental targets. With a view to the current state of our knowledge about climate change impacts ranging from profound uncertainties to outright ignorance, providing the necessary information to set those environmental targets is extremely difficult at best and completely impossible according to many. Nevertheless, systematic attempts to search for the "ultimate reasons" for climate protection in various impact sectors are useful in sorting out thorny issues about climate vulnerability, impacts, adaptation, and the assessments thereof.

This is the very strategy the Potsdam Institute for Climate Impact Research is implementing in its project about Integrated Assessment of Climate Protection Strategies (ICLIPS). The approach is a bi-directional analysis from tolerable climate impacts to costs associated with emission reduction measures to keep the climate system within the derived climate window, and vice versa. The project seeks to define climate response functions for various climate sensitive sectors. Social actors can then use the response functions to define their perceived tolerable levels of climate impacts. These constraints would then define regional tolerable climate windows. By using an appropriately formulated integrated climate and economic model, cost-effective emission paths will be derived that keep the global climate system within those tolerable windows. In the opposite direction, the model should be able to compute through the traditional analytical path form emission scenarios to climate change to damages in numerous impact sectors.

Costs associated with various tolerable climate windows as well as the benefits secured by them in terms of natural biophysical units could then be compared in a further analysis. In working out the cost-effective emission path, of course, costs in various future time points would need to be compared. This intertemporal optimization problem would adopt discount rates that are consistent both with economic theory and empirical observations.

Discounting is a central issue in policy analyses of long-term environmental problems like climate change. Debates about the appropriate techniques and the ethically acceptable rates are abound. This paper has argued that in deciding about life or death dilemmas, manipulating the discount rate is not the right strategy. It does not serve the environmental objective and distorts the internal consistency of the analysis. The more promising strategy is to achieve solid consensus about the socially desirable environmental goal and find the nest strategy to implement them.

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