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Intergenerational equity and discounting

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A standard framework is presented as an underlying model for the discounting debate. Views and proposals for the techniques and rates of discounting are assessed. Alternative modeling frameworks for studying intergenerational equity issues are evaluated with the result that the basic insights they provide do not differ very much. Results from model experiments involving different discount rate proposals show that fudging the discount rate does not lead to efficient climate policy. Three major clusters of opinions are identified regarding the applicability of cost-benefit analysis to the climate change problem and the appropriate discount rate to use. It is concluded that under some very special circumstances the cost-benefit rule should be abandoned and cost-effective strategies implying standard discount rates should be sought to reach clearly defined and justified environmental targets.

Keywords: integrated assessments, climate change, discounting, equity, climate policy

1. Introduction

This paper has been commissioned to prepare a survey of current thinking about discounting in the context of the climate change problem. 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.

In the early 1980s, a project at the Resources for the Future produced a standard setting study on the discounting issue [14]. These results have been subsequently revised in light of new theoretical research and empirical evidence. Lind [16] 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. Manne [19] 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 [32] 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 arguments and new developments in the debate on discounting, the “correct” techniques and rates, and, as is sometimes inevitable, looks at the broader question of the applicability of cost-benefit analysis to long-term environmental issues like climate change. Section 2 outlines a basic analytical framework referred to by many participants in the debate. This is followed by an admittedly incomplete survey of views and proposals for discounting in climate policy analyses in section 3. Results from a major workshop devoted to the problem of intergenerational equity and discounting are presented in section 4. Section 5 briefly looks at the modeling frameworks adopted for long-term issues. Section 6 raises the question whether manipulating the discount rate is a useful attempt to derive efficient climate protection policies and concludes that, due to the specific features of the climate problem, the appropriate framework to use is cost-effectiveness. Section 7 presents some concluding remarks.

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 [29] and explained in some detail by Manne [19] and Nordhaus [24]. Our discussion here is based on Solow [35]. 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 ([35, p. 82]), the problem is to maximize

$$W = \int_0^\infty e^{-(a-n)t} U(c)\,\mathrm{d}t, \tag{1}$$

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

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

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

$$\frac{U''(c^*)\mathrm{d}c^*/\mathrm{d}t}{U'(c^*)} = \frac{c^*U''(c^*)}{U'(c^*)}\frac{1}{c^*}\frac{\mathrm{d}c^*}{\mathrm{d}t} = -j\frac{(\dot{c}^*)}{c^*} = -(r^* - a), \tag{3}$$

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

$$r^* = a + jf. \tag{4}$$

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, the elasticity of the marginal utility of consumption j, and the growth in consumption f.

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 [14] 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 is 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" ([14, p. 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 [15]. 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.

We can conclude from this section that discounting has perplexed economists much before the multi-century long-term environmental problems entered the agenda. The dilemma between analytical consistency and ethical appeal remains intriguing.

3. Recent developments in the discounting debate

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 [4]. 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.

Some ideas behind certain positions in the current debate on discounting go back to almost two decades. d'Arge et al. [8] depict a simple intergenerational model of the CO_2 problem and explore the emerging discount rates under a series of ethical systems (ranging from utilitarian to Rawlsian to libertarian) and depending on whether compensation of the future generation is possible and actually occurs or not. Under the assumptions characterizing this model (e.g., the future generation includes the entire future into infinity), two important conclusions stand out. First, if no actual compensation occurs among generations, the market rate of return has no relevance for discount rates. This is the main argument picked up and advanced by Lind and Schuler [18] to reject the relevance of discounting in intergenerational analyses. Second, if the chosen ethical system is such that all future generations are to be evaluated equally, then the optimal present policy is to reduce CO_2 emissions as much as possible.

Much has been speculated about the relationship between sustainable development and climate change. Discounting issues are particularly contentious in this context. Chichilnisky [5] proposes two axioms to depict sustainable development, derives the implied welfare criterion and compares it to other welfare criteria widely used in economic analyses. She finds that the discounted utility criterion does not satisfy her axioms and thus it is inadequate for analyzing sustainable development issues. Tol attempted to include the Chichilnisky axioms in his FUND model but the results turned out to be difficult to interpret, as will be discussed in section 6.

Proposals to bend the discount rate in order to bring far-future concerns like climate change impacts closer to policy makers today range from hyperbolic discount rates to flat zero rates for all intergenerational problems (e.g., [22]). Henderson and Bateman [12] first present an empirical survey of how inconsistently discount rates have been defined and used for public policy projects by different government agencies in Britain and the United States. The authors then take survey results that estimate society's propensity to discount future lives saved and find that the revealed relationship is hyperbolic discounting. This is congruent with what behavioral sciences detect as well. On this basis, the authors propose that in cost-benefit analyses of intergenerational projects studies using exponential discount rates should be complemented with those of hyperbolic discount rates in order to improve insights into the various policy options.

Weitzman [45] takes the profound uncertainty characterizing all aspects of the distant future (many generations or centuries) as a starting point for a simple model in which certainty-equivalent discount factors and rates are identified under a full set of possible futures, each characterized by some non-zero probability to become true. This model serves as a basis to derive his proposition: the "lowest possible" interest rate should be used for discounting the far-distant part of any investment project. According to Weitzman, the model demonstrates that for such projects certainty-equivalent social discount rates should be used that decline over time from around today's estimated best average value down to the smallest conceivable rates for the far distant future.

The problem arising from the hyperbolic or other declining rates of discounting is time inconsistency. Assume a CBA is conducted by using hyperbolic discounting in year T. Repeating the same assessment two decades later in year $T + 30$ would imply revaluing the future streams of costs and benefits for the period $T > 30$ by using the same hyperbolic rates but starting from the high near-term rate applicable in year $T + 30$. The resulting optimal policy for the period $T > 30$ in most cases will be different from what the original analysis determined for that period. Nonetheless, this might not necessarily be a critical point considering the fact that policy making for any long-term issue is by necessity a sequential decision making problem. The task for today's analysts is not to identify the once-for-all optimal strategy because policies will be regularly updated in the future in light of new information or on the basis of changed circumstances.

Another batch of proposals argue that certain social sectors, economic activities or environmental domains should receive preferential treatment and maintain that the proper way of implementation is to apply preferential (typically lower) discount rates in comparing intertemporal flows of goods and services in these areas. In their Structural Integrated Assessment Model (SIAM), Hasselmann et al. [10] use different discount factors and as a result different discount rates for abatement costs and climate damage costs.

Several arguments crop up throughout the paper. The argument of "possible differences in public time preference for different amenities" should justify why the discount rates are regarded independent (p. 363), while the point "potential deterioration of future living conditions through an irreversible change" is considered a loss in value irrespective of when it occurs combined with the reasoning that many climate impacts involve non-monetary losses for which equivalent monetary values for future generations increase over time thus "the growth in GDP approximately cancels the normal economic discount factor, yielding a zero net discount rate" (p. 372). Recognizing the willingness to pay principle, the authors note that only the public perception of the value of a future stable climate is relevant in policy making (cf. the Mock Referendum proposal by Kopp and Portney in section 4), they find that in the context of the SIAM model a climate policy compatible with sustainable development emerges only if discount rates for climate damages are much lower than for abatement costs.

Differential discount rates are not unprecedented in reality, but they are difficult to justify within the same analytical framework, as it is apparent from the critique of the Hasselmann practice by Nordhaus [25]. Moreover, many authors point out at the problems associated with differential discount rates in general. Heal [11] comments on many different arguments but concludes that there is no conceptual ground to differential discounting.

This section has shown the variety of efforts to overcome the intuitive uneasiness about the fact that standard discount rates and exponential discounting lead to basically ignoring even cataclysmic events if they are a century or more away. The arguments behind these efforts are diverse. Section 6 will explore their implications for climate policy in more detail.

4. Proposals for long-term discounting and modeling

In this section we explore the question whether discounting is appropriate for social decisions affecting the long term at all. The debate has been long-standing among economists and has broadened to involve many others outside the economist community in the context of climate change. Some participants in the debate say yes without hesitation, others completely dismiss the idea of discounting. Late 1996, the Energy Modeling Forum of Stanford University and the Resources for the Future (Washington, DC) organized a workshop to look at the issue of discounting in the context of projects or decision problems affecting the very long-term future [27]. The sampler of views and opinions in this section is based on contributions to that workshop.

Those who support the idea of using a standard discount rate for evaluating long-term problems derive their arguments from a broad range of conceptual models. Arrow [1], for example, maintains that discounting pay-offs in the far future is largely an ethical problem. He observes that although individuals recognize moral arguments about their responsibilities for future generations, they tend to treat themselves better. Taking some simple principles of agent-relative ethics as a starting point, Arrow constructs a simple non-cooperative game among successive generations in which each generation is selfish. This model is then used to analyze irreversible investments across several generations. Arrow demonstrates that in the context of this simple model there is no argument for discounting irreversible investments at a preferential or lower discount rates. Bradford [3], Montgomery [23], Smith [34] and Manne [21] present partly very different lines of arguments, formulate models to depict one or the other specific feature of deep-future discounting, but come, with different qualifications, to largely similar conclusions: CBA for very long-term projects is a useful tool and discounting should follow standard procedures.

Bradford [3] takes a look at a series of public policy choices, key characteristics of the problems behind them, and implications of various policy options. He argues that deep future projects are simply longer-term versions of ordinary projects and one should consider the probability distributions of the resulting consumption patterns but use the market discount rates to compose them over time. Although implications of climate change for non-market goods and services raise some serious problems of valuation, cost-benefit analysis is deemed to be helpful in decision making.

Manne [21] also argues that projects whose effects spread out over centuries should be treated as longer versions of standard projects. Cost-benefit analysis can be used accordingly. In contrast to Weitzman, however, Manne warns that market-based discount rates might decline with an eventual slowdown in economic growth. Nevertheless, discount rates for even long-term analysis must be consistent with those used in evaluation of conventional investments. The important factor behind this argument is that a necessary condition for economic efficiency is that the rate of return on capital should be identical between conventional and environmental investments.

Dasgupta et al. [9] take a closer look at the logic underlying social discount rates. They also argue that investments with long-run effects should be investigated with the same conceptual treatments as "normal", short-run projects. Using a simple model example of climate change, they show that appropriate social discount rates depend on the numeraire and, as such, the methods for estimating these rates depend on the institutional setting in which social cost-benefit analysis should be used. They clearly reject the idea of sector specific discount rates, i.e., the preferential treatment of environmental investments. As for the discount rates, however, the authors show that if consumption and production activities involved an environmental spill-over, the social rate of return on investment and thus social rates of discount can be zero or even negative even when the private rates are positive.

Kopp and Portney [13] emphasize that cost-benefit analysis in the support of environmental policies is a useful analytical framework and the usual treatment of environmental bads (the damage functions – discounting approach) is suitable up to a 30–40 year time horizon. They argue that while CBA remains a valid framework, a different conception of CBA is needed and they propose the "mock referendum" approach. The central idea is to provide a carefully selected sample of individuals with a balanced and value-neutral package on climate change, its impacts and mitigation costs. The packages would contain information about the policies' effects as well as the expected implications of a non-intervention. It is important to include information about spatial and temporal distribution of damages and mitigation cots. Individuals can then make their own choices about the right level of climate policy. Kopp and Portney argue that these choices then would be consistent with the individuals' preference-based valuation of costs and benefits as well as with their preference-based discounting.

Reservations against and ambivalence towards cost-benefit analysis characterize Lind's [17] views as well. He argues that while CBA can yield useful information, it cannot provide a complete basis for decision making or for deriving optimal policy. Lind agrees with Schelling [32] that the fundamental choice involved in projects of long time horizon is whether to transfer resources to people distant in time and, possibly, in space as well. The primary reason for Lind's rejecting the exponential discount rate and the optimal growth framework is that in these long-term projects there is a series of generations involved across which transfer is impossible to guarantee. This means that no compensation is possible in either direction, thus the compensation test fails. Lind's proposal to those who want to use cost-benefit analysis is to follow the standard discounting procedure in the optimal growth framework but display time paths of consumption rather than just the discounted net present value of consumption streams so that a more informed judgement can be made when comparing alternative policy proposals.

Among those who reject the relevance of CBA and discounting to the climate problem, Schelling [33] points out that given the asymmetries in climate policies (costs to be shouldered by developed countries today, benefits accruing to developing countries in the far future) climate protections is very much like foreign aid. CBA and discounting can help little to determine the appropriate magnitude and distribution of such transfers but intuitively it appears to be much more effective to make those transfers directly to people in developing countries today than indirectly via climate protection to their descendants several generations away.

In recent years, several economists have proposed to use discount rates for very long-term projects that do not remain constant forever but decline over time. (Note that this approach is different from the optimal growth framework in which the effective discount rate is driven by the declining marginal productivity of capital which is determined by an externally defined, ultimate and asymptotic limit to economic growth.) The general argument is that possible very long-term implications of current activities should be brought to policy makers' attention and one possible way to do so is to reduce the discount rate at which those effects are converted to present value.

Weitzman [46] builds his arguments on expected future technological development. According to his line of thought, there is no reason to think that mankind's ability to create new inventions will decline, thus there is no reason to expect that productivity of investments will diminish even in the distant future. This expected increase in productivity is the key factor determining welfare of future generations. Moreover, exactly because of the long time horizons characterizing the "deep future" problems, decision makers can regularly revisit the issue using standard cost-benefit calculations and then current discount rates. According to Weitzman's argument, this will ensure that relevant policies can be revised accordingly. Nevertheless, based on his model presented earlier, Weitzman argues for a declining discount rate starting at the low end of the normal discount rates of 3–4% for the first 25 years, 2% for the next 50 years, 1% for the period 75–300 years from now and 0 beyond 300 years.

Similar proposal is put forward by Cline [7] who offers the use of declining discount rates for long-term issues as a possible compromise between the descriptive and prescriptive positions. In his earlier analysis, Cline [6] proposed to use what he calls the Social Rate of Time Preference (SRTP) approach where SRTP equals the rate of pure time preference, which would be zero for social cost-benefit analysis, plus the elasticity of marginal utility multiplied by the growth rate of per capita income. In this new paper, Cline proposes to use 5% for the first 30 years (basically the lifetime of the present generations) and 1.5% beyond this, but starting already from year one. This leads to a jump in the discounted streams of costs and benefits but the author maintains that this minor inconsistency is an acceptable price for striking a compromise.

In his input to the same workshop, Nordhaus [26] used the DICE model to compare the various discounting proposals. His most important conclusion is that fudging the discount rate does not lead to efficient climate policy (see below). His result clearly show, however, that for analyzing long-term environmental problems in general, and the climate change problem in particular, preferential (lower) discount rates for environmental goods and services work out better than lower discount rate for all goods and services.

Implications of the different discount technique and discount rate proposals for climate policy will be explored in a later section. Before turning to these implications, it is useful to look at a closely related matter, namely what modeling framework to use.

5. 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 [2] 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 [6]) with a twist: for intragenerational shadow prices of capital, they take the sum of time and growth discount rates, 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 earlier in this paper).

The trouble with the above and similar other models is that their OLG formulation does not fit the analytical requirements of the GHG problem. Stephan and Müller-Fürstenberger [36] and Stephan et al. [37] 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, 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 [20] arrives at similar conclusions by linking an OLG-based intertemporal equilibrium model to a reduced-form version of the MERGE model. Experiments conducted with these 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.

The debate between proponents of the ILA an OLG frameworks continues. At this point, it seems that ILA as an abstraction offers a very convenient framework for long-term analysis without significantly distorting the policy insights.

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

Nordhaus [25] 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 in the optimal solutions involving different discount rates 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 [40] 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 [11] logarithmically declining discount factor, with Rabl's [28] discounting approach in which the discount rate drops to zero at a predetermined time in the future, and with Chichilnisky's [5] 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 CO_2 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 its own welfare-dependent target and, therefore, produced partly counterintuitive results. The difficulties partly arise from the fact that the FUND model has a finite horizon. Applying the Chichilnisky criterion with welfare in 2200 leads to a rather trivial result. In FUND, climate change is not a real threat to welfare, while drastic emission abatement is. Applying Chichilnisky thus reduces optimal emission abatement.

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%) is more than 10% below the lowest non-cooperative concentration (using Heal discounting at 1%). 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 a 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 the conveyor belt) is one example (see Rahmstorf [30,31], Stocker and Schmittner [38] for the geophysical details; and Tóth et al. [42] for an analysis of the associated global climate target and permitted emission corridor).

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

Tol [39] 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 policy makers 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.

The answer to the question raised in the title of this section is clearly no. Tilting the discount rate downward would clearly result in larger near-term efforts in climate protection but the emerging policy would be neither environmentally effective nor economically efficient. This raises the issue whether it is really the discount rate at the root of the problem or there are serious reasons that justify abandoning the cost-benefit framework and use the cost-effectiveness framing instead.

7. Closing remarks

Returning to the central question of this paper: what should be the appropriate discount rate to compare costs and benefits over time? More broadly, are techniques of CBA applicable to the climate change problem at all? 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 [25,26]), 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 (see Tóth [41]). 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 policy makers 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.

Switching from cost-benefit to cost-efficiency framing has an important implication for discounting. By setting environmental targets directly both the difficulties of valuing non-market environmental assets and the reduction of far-future economic and environmental benefits due to discounting are resolved. This means that in the search for cost-effective strategies to reach pre-defined environmental targets standard market-based discount rates should be used just as for any other investment decision. This still raises intergenerational problems in sharing the mitigation burden, but they can be easily managed in an intertemporal cost-effectiveness framework.

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 impact 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 can be derived that keep the global climate system within those tolerable windows. In the opposite direction, the model is able to compute through the traditional analytical path from emission scenarios to climate change to damages in numerous impact sectors (see Tóth et al. [43,44]).

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 best strategy to implement them.

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