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Intertemporal Evaluation Criteria for Climate Change Policy: The Basic Ethical Issues

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EXECUTIVE SUMMARY

The evaluation of long-term effects of climate change in cost-benefit analysis has a long tradition in environmental economics. Since the publication of the *Stern Review* in 2006 the debate about the "appropriate" discounting of future welfare and utility levels was revived and the most renowned scholars of the profession participated in this debate. But it seems that some contributions dealing with the *Stern Review* and the Review itself mixed up normative and positive issues to defend the own position. Furthermore, as we argue in this contribution, it also seems that the debate misses the heart of the problem. The aim of this work is to bring together economic and philosophical reasoning about justice and intergenerational equity in the context of climate change. So we adopt the *normative* view in order to present the most important ethical issues that, particularly in the context of climate policy, are most relevant for the choice of intertemporal welfare criteria. We investigate the properties of the Maximin, the Undiscounted Utilitarianism, Discounted Utilitarianism and more recently developed hybrid criteria. Subsequently we explore whether ethical considerations may also be helpful to determine the parameter values which, after the choice of some type of intertemporal social welfare function, are needed to specify the concrete criterion that is employed to make decisions on climate policy. Namely we try to delimit the range for the inequality aversion parameter (η) and for the pure rate of time preference (ρ).

Our findings are, at least from an ethical point of view, rather pessimistic. Following Max Weber's famous "Wertfreiheitspostulat" it can never be decided objectively and on a scientific base what should be considered as an equitable distribution e.g. among generations. Nevertheless, our considerations allow some tentative conclusions. First, the decision between undiscounted and discounted utilitarianism turning down the undiscounted version as often postulated in the literature neither seems to be appropriate nor necessary. To endorse equal treatment of generations and thus undiscounted utilitarianism at the fundamental level does, moreover, not preclude that some, possibly extremely small pure time discount rate is applied through which the uncertainty of future costs and benefits is taken into account. And second, as a consequence, the decisive parameter in intertemporal decisions is the η. We agree with Stern's argumentation for an extremely small pure rate of time preference, but we fundamentally disagree with his low choice of η of 1. We recommend values of η that are closer to 2 than to 1. The question of principle whether to use undiscounted or discounted utilitarianism is to some degree futile concerning practical policy implications. What in the end matters much more is the selection of specific parameter values for which some well-founded ethical judgment, however, is often hard to provide.

DAS WICHTIGSTE IN KÜRZE

Die Bewertung der langfristigen Auswirkungen des Klimawandels im Rahmen von Kosten-Nutzen Analysen hat eine lange Tradtion in der Ökonomie. Mit der Veröffentlichung des *Stern Reports* im Jahr 2006 wurde die Debatte um die "angemessene" Diskontrate von zukünftigen Wohlfahrts- und Nutzenniveaus wiederbelebt und die angesehensten Ökonomen haben zu dieser Debatte beigetragen. Aber es hat den Anschein, dass die Publikationen zum *Stern Report* und der Report selbst normative und positive Themen vermischt haben, um die eigene Position zu verteidigen. Wie wir in diesem Papier argumentieren geht die Debatte am Kern vorbei. Das Ziel dieser Arbeit ist es, ökonomisches und philosophisches Denken zu Themen der Gerechtigkeit zwischen den Generationen im Zusammenhang mit dem Klimawandel zu vereinen. Wir nehmen daher die *normative* Perspektive ein und präsentieren die wichtigsten ethischen Probleme, die für die Auswahl eines intertemporalen Wohlfahrtskriteriums entscheidend sind. Wir untersuchen die Eigenschaften des Maximin-Kriteriums, des undiskontierten Utilitarismus, des diskontierten Utilitarismus und neueren, hybriden Kriterien. Daraufhin untersuchen wir, ob ethische Überlegungen hilfreich seien können, um Paramterwerte zu bestimmen, welche für die jeweiligen Wohlfahrskriterien entscheidend sind. Wir wollen eine plausible Bandbreite für die zentralen Variablen geben, dem Parameter zur Ungleichheitsaversion (η) und der Rate der reinen Zeitpräferenz (ρ).

Unsere Resultate sind, zumindest aus ethischer Sichtweise, eher pessimistisch. Beachtet man Max Weber's "Wertfreiheitspostulat", kann niemals objektiv und auf wissenschaftlicher Basis festgelegt werden, was eine gerechte Verteilung, z.B. zwischen den Generationen, ist. Trotzdem können wir einige vorsichtige Schlußfolgerungen ziehen. Die Wahl zwischen undiskontiertem und diskontiertem Utilitartismus scheint, anders als die geläufige Literatur behauptet, irrelevant zu sein. Um, wie es der undiskontierte Utilitarismus tut, eine Gleichbehandlung der Generationen zu gewährleisten, kann eine marginal positive reine Zeitpräferenzrate verwendet werden, die die Unsicherheit zukünftiger Kosten und Nutzen berücksichtigt. Zweitens, als Folge davon, ist der entscheidende Paramter das η. Wir stimmen dahingehend mit Stern's Argumentation für eine marginal positive Zeitpräferenzrate überein, aber wir wiedersprechen vehement seiner sehr niedrig gewählten Wahl von $\eta = 1$. Wir empfehlen Werte von η die näher an 2 sind als an 1. In der Praxis ist die Wahl zwischen undiskontierten und diskontierten Wohlfahrtsfunktionen bis zu einem gewissen Grad unerheblich. Was vielmehr wichtig ist, ist die genau begründete Wahl der entscheidenden Parameter, was aus dem ethischen Blickwinkel, oftmals sehr schwierig ist.

INTERTEMPORAL EVALUATION CRITERIA FOR CLIMATE CHANGE POLICY: THE BASIC ETHICAL ISSUES

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ABSTRACT - The evaluation of long-term effects of climate change in cost-benefit analysis has a long tradition in environmental economics. Since the publication of the *Stern Review* in 2006 the debate about the "appropriate" discounting of future welfare and utility levels was revived and the most renowned scholars of the profession participated in this debate. But it seems that some contributions dealing with the *Stern Review* and the Review itself mixed up normative and positive issues to defend the own position. Furthermore, as we argue in this contribution, it also seems that the debate misses the heart of the problem. The aim of this work is to bring together economic and philosophical reasoning about justice and intergenerational equity in the context of climate change. So we adopt the *normative* view in order to present the most important ethical issues that, particularly in the context of climate policy, are most relevant for the choice of intertemporal welfare criteria. Subsequently we explore whether ethical considerations may also be helpful to determine the parameter values (or at least to delimit their range) which, after the choice of some type of intertemporal social welfare function, are needed to specify the concrete criterion that is employed to make decisions on climate policy.

Keywords: Intertemporal ethics, Distribution, Discounting, Climate Change
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I. INTRODUCTION

The results of cost benefit analysis crucially depend on the welfare criteria that are used to evaluate the streams of well-being over time that are generated by the investment projects under consideration. In economics and philosophy there is a long lasting and rather controversial debate as to which type of intertemporal social welfare function and, in particular, which social discount rate should be applied. This debate has been revitalized in the last few years because, especially since the release of the Stern Review in 2006, it has become clear which effect the choice of the social discount rate has on the design of climate policy. An important question in this context is in which way and to which degree the interests of future generations should be taken into account when decisions with long-run consequences are made. From this perspective the decision to apply a specific intertemporal evaluation criterion becomes a matter of ethics, i.e. of justice between generations.

There exist two opposing "schools" in economics which have completely different positions concerning the importance of intergenerational ethics for intertemporal evaluation (see Aldy et al. (2010), p.912). On the one hand there is the positive ("descriptive") school for which ethical judgment is redundant since empirically observable market interest rates should be the benchmark for the determination of the social discount. On the other hand there is the normative ("prescriptive") school which has its roots in classical welfare economics and for which explicitly formulated normative criteria are of much importance. For this school an ethically oriented debate on the properties and implications of different intertemporal evaluation criteria and their basic norms is essential.

In this paper we will adopt the perspective of the normative school (see also Roemer J. (2011), for an excellent defense of the ethical position). Our main objective then is to present the most important ethical issues that, particularly in the context of climate policy, are most relevant for the choice of intertemporal welfare criteria. We will proceed as follows. In Section 2 we present various classes of intertemporal social welfare functions well-known from optimal growth theory (i.e. maximin, undiscounted utilitarianism, discounted utilitarianism and some recently developed hybrid criteria) and discuss which desirable and undesirable properties can be attributed to them. In Section 3 we explore whether ethical considerations may also be helpful to determine the parameter values (or at least to delimit their range) which, after the choice of some type of intertemporal social welfare function, are needed to specify the concrete criterion that is employed to make decisions on climate policy. In Section 4 we summarize and conclude.

II. ETHICALLY RELEVANT PROPERTIES OF DIFFERENT TYPES OF INTERTEMPORAL SOCIAL WELFARE FUNCTIONS

A. Preliminaries

As common in the literature we assume that c_t denotes well-being in each period $t = 1, 2, \ldots$. This means that the vector of various determinants of well-being, i.e. material consumption, leisure, environmental quality etc, is mapped into the real-valued indicator c_t. The severe problems of measurement and aggregation of c_t are not treated in this paper[1]. It is only for terminological convenience, that in the following the variable c_t will be identified with consumption in period t . Time is discrete, with each period of time $t = 1, 2, \ldots$ representing just the lifespan of one single generation. So generations do not overlap, and for the sake of simplification, we suppose that population is constant over time thus neglecting the ethical aspects of population change[2]. If some technology and some initial resource endowment are given there is a class Γ of feasible consumption paths $(c_1, c_2, \ldots)$ of infinite length. These consumption paths are evaluated by an intertemporal social welfare function $W(.)$ which is weakly monotone in all variables and may assume values in the interval $[-\infty, +\infty]$.

B. Maximin

This criterion dates back to Rawls´ "difference principle" (although Rawls, J. (1971) himself did neither accept the denomination maximin nor the application of this criterion in the intergenerational context). It was Solow, R. (1974) - as an attempt to be "plus Rawlsien que le Rawls" - who applied this criterion to the Dasgupta-Heal-Solow growth model, in which the input of an exhaustible resource is continually substituted by reproducible man-made capital. Given an infinite number of generations the minimum level of consumption along a given consumption path may not exist. Therefore, the maximin social welfare function must in this case be defined as

$$W(c_1, c_2, \ldots) = \inf_{t=1,2,\ldots} c_t \tag{1}$$

This social welfare function satisfies two commonly shared ethical objectives that play a major role in the intergenerational context.

[1] d'Aspremont, C. and Gevers, L. (1977) offer a very comprehensive axiomatic approach towards different social welfare functional. Roemer, J. (1996) summarizes the extensive literature and contributions that deal with the measurability of well-being and its relevance for social welfare functional in a very elegant manner.

[2] We refer the reader who is interested in situations with a changing population to Blackorby, C. , Bossert, W. and Donaldson, D. (1995).

(i) All generations have an equal weight in social evaluation, such that in particular future generations are not discriminated simply because they have the bad luck to appear later on the time axis. This intergenerational neutrality also means that the value of the social welfare function (1) is not changed even if an infinite permutation of a given consumption path is made. For a long time (see already Sidgwick, H. (1874)), equal treatment of generations has been considered to be the basic requirement for intergenerational fairness. Maximin also respects some albeit rather weak version of the Pareto principle: If consumption does not decrease for any generation the new path obviously is not worse than the original one according to (1).
(ii) The maximin rule (1) implements quite specific non-decreasing and thus sustainable paths as optimal solutions when these are technically feasible: Assume that there exists a strictly positive consumption level $\overline{c}$ that, for the given technology and the given initial resource endowment can be attained by any generation. Then it is clearly excluded by application of (1) that some later generation´s consumption falls below $\overline{c}$ and some earlier generation enjoys consumption above $\overline{c}$. If such a constant consumption path $(\overline{c}, \overline{c}$ is Pareto optimal it maximizes social welfare according to (1) among all feasible paths. This was the situation considered in Solow, R. (1974) classical paper for the special case of a Dasgupta-Heal-Solow economy.

Even though the maximin rule shows these ethically appealing properties it also has some serious disadvantages such that it generally only serves as some benchmark criterion which is not considered to be an appropriate instrument for intertemporal evaluation. But this standard view may be questioned if the economy's state of development is already very high and maximin does not apply to levels of material consumption but to basic and partly non-substitutable goods as staple food or health (see Roemer J. (2011)).
(i) It does not respect more demanding versions of the Pareto criterion , i.e. valuation according to (1) is completely insensitive to increases in consumption as long as the minimum/infimum of consumption does not change. In particular, the *strong* Pareto principle is violated, which means that any increase of consumption along a given path should give a new path that is strictly preferred to the original one. To give an example just consider the two consumption paths $\left(\frac{1}{2}, \frac{1}{3}, \frac{1}{4}, \dots\right)$ and $\left(1, \frac{2}{3}, \frac{1}{2}, \dots\right)$. Both have the same infimum equal to zero but in each period the second path has a higher level of consumption than the first one. In the case of a finite number of generation this problem can easily be solved by adopting the leximin criterion, but with an infinite number of generations such an extension is neither straightforward nor does it allow a comparison of all paths.
(ii) The maximin criterion forbids any investment of an earlier generation to increase the level of well-being of future generations above the level enjoyed by

itself - irrespective of the extent of that increase and the number of future generations which would benefit. To give an example we start from the constant consumption path $(1, 1, 1, \dots)$ and assume that the economy under consideration is so productive that the path $(\frac{999}{1000}, 2, 2, \dots$ is also technically feasible. I.e. if one single generation (the first one) makes a sacrifice of only $\frac{1}{1000}$ units of consumption each subsequent generation could double its level of well-being. Nevertheless, the maximin rule deems this path as inferior to the constant consumption path. Strict application of maximin thus condemns the economy to stagnation and precludes economic growth which in the standard way is based on investment. It was this reason why Rawls, J. (1971) did not recommend the difference principle to make choices in the intergenerational context.

C. Undiscounted Utilitarianism

In his seminal paper on optimal growth theory Ramsey, F. (1928) used undiscounted utilitarianism to evaluate and compare feasible consumption paths. This class of criteria shares some advantages and disadvantages with the maximin rule but has merits and shortcomings of its own. The standard version of an undiscounted utilitarian social welfare functions reads as

$$W(c_1, c_2, \dots) = \sum_{t=1}^{\infty} u(c_t) \tag{2}$$

where $u(c)$ - usually defined for all consumption levels $c > 0$ - is a strictly monotone increasing utility function through which the well-being of each generation is assessed before it enters social evaluation. Often an isoelastic utility function given by $u(c) = \frac{c^{1-\eta}}{1-\eta}$ is employed where the elasticity of marginal utility $\eta \geq 1$ (with $\eta \neq 1$) indicates the degree of inequality aversion in social evaluation. For $\eta = 1$ the utility function is defined as $\ln c$ (which is justified since $\lim_{\eta \to 1} = \frac{c^{1-\eta}}{1-\eta} = \ln c, \forall c > 0$). The main ethical advantages of undiscounted utilitarianism are as follows:

(i) Just as the maximin rule application of an undiscounted utilitarian social welfare function according to (2) implies equal treatment of all generations and thus respects the fundamental postulate for intergenerational justice. Welfare is not changed when the consumption levels of a finite number of generations are permuted if, as assumed in (2), the utility function $u(c)$ is the same for all periods. Note, however, that this property is not an implication of the undiscounted utilitarian approach as such but anonymity as a separate assumption. Concerning distribution in the atemporal setting, i.e. within a society in a certain period of time, it is moreover quite common in welfare economics to make judgments with unweighted sums of utility.

(ii) Undiscounted utilitarianism ensures sustainable development if the economy under consideration is productive in an intuitive sense: If some generation makes a consumption sacrifice thus expanding the capital stock then it will be possible for any later generation to increase its consumption by more than this earlier sacrifice. Then it follows from a general argument (see Asheim, G., Buchholz, W. and Tungodden, B. (2001)) that a non-decreasing consumption will never maximize the objective function (2). So it is ensured that only non-decreasing paths are selected by applying an undiscounted utilitarian criterion. Along such paths no generation consumes more than it concedes to its successors.
(iii) If the utility function $u(c)$ is concave what is usually assumed then a rank-preserving Pigou-Dalton transfer from a rich generation with high consumption to a poorer generation with lower consumption increases aggregate welfare (2) (see in a general welfare theoretic framework Atkinson, A. (1970)). Thus undiscounted utilitarianism is also useful to take equality of the distribution of well-being among generations into account which, as an ethical objective, is conceptually different from the equal treatment of all generations in the welfare function. Adopting utility functions $u(c)$ with more or less curvature, i.e. varying the parameter η in the case of an isoelastic utility function, makes it possible to capture different degrees of inequality aversion in social evaluation. Seen from this perspective the maximin criterion is the extreme case where inequality aversion η is infinite. Classical utilitarianism, where $u(c) = c$ and the pure consumption levels are summed up in (2), reflects the extreme in which inequality aversion is completely absent.

On the other hand undiscounted utilitarianism has some properties which are less desirable.
(i) Given a certain utility function $u(c)$ the utility sum of many consumption paths will be plus or minus infinity. Solely applying the scalars obtained by (2) welfare of all these paths is not comparable. But it is straightforward to extend the ranking of consumption paths by using overtaking or catching up criteria. Thus, e.g., a consumption path $(c_1^a, c_2^a, \dots)$ is strictly preferred to a consumption path $(c_1^b, c_2^b, \dots)$ if there is a period $\tilde{T}$ such that for all $T > \tilde{T}$ the inequality

$$\sum_{t=1}^{T} u(c_t^a) > \sum_{t=1}^{T} u(c_t^b) \tag{3}$$

holds. Weak preference is obtained if condition (3) is fulfilled with weak inequality $\geq$. For fundamental reasons it is, however, not possible to make a further extension of the partial ordering given by (3) which respects stronger versions of the Pareto principle and would allow us to make a comparison between any two consumption paths.

(ii) While in a productive economy maximin is too much in favor of the present undiscounted utilitarianism may be too much in favor of the future demanding excessively high savings from earlier generations. For an illustration assume that, given a strictly increasing utility function and starting from a constant consumption path $(\bar{c}, \bar{c}, \ldots)$, the consumption sacrifice s in the first generation allows any subsequent generation to increase its consumption by some $\epsilon > 0$. Then, as long as $u(\bar{c} - s) > -\infty$, the consumption path $(\bar{c} - s, \bar{c} + \epsilon, \bar{c} + \epsilon, \ldots)$ will dominate $(\bar{c}, \bar{c}, \ldots)$ according to the criterion (3) irrespective of how small ϵ is. This well-known argument against undiscounted utilitarianism (see already Chakravarty, S. (1969) , Rawls, J. (1971), Arrow (1999) and Asheim, G. (2010)), however, needs some qualification as it does not hold for any path from which saving starts. Suppose that the utility function is $u(c) = -c^{-1}$. Let the initial consumption path be $(1, 2, 4, 8, \ldots)$ which then has aggregate welfare -2. Now assume that generation 1 saves $\frac{1}{4}$ which increases consumption of any subsequent generation by the uniform amount $\frac{1}{10}$. Welfare along the new consumption stream $\left(\frac{3}{4}, 2 + \frac{1}{10}, 4 + \frac{1}{10}, 8 + \frac{1}{10}, \ldots\right) = \left(\frac{3}{4}, \frac{21}{10}, \frac{41}{10}, \frac{81}{10}, \ldots\right)$ is smaller than along the path $\left(\frac{3}{4}, \frac{21}{20} \cdot 2, \frac{21}{20} \cdot 4, \frac{21}{20} \cdot 8, \ldots\right)$ whose welfare is $-\frac{4}{3} - \frac{20}{21} \cdot 1 = -\frac{48}{21} < -2$. So the new path is inferior to the original one. This means that the investment of generation 1 does not improve welfare even though all generations from generation 2 on benefit from an equal increase of consumption. If saving of generation 1 exceeded $\frac{1}{2}$ then any increase in future consumption along the given initial path would not be sufficient to restore welfare to its original level. Therefore, if we do not start from a constant, but from a strictly monotone increasing consumption path undiscounted utilitarianism may well be able to prevent excessive saving and the concomitant overburdening of earlier generations. Restricting the speed of growth to an ethically acceptable degree to protect the interests of earlier generation is not a priori excluded in the framework of undiscounted utilitarianism (see Asheim, G. and Buchholz, W. (2003) for a further elaboration of this argument).

D. Discounted Utilitarianism

Most frequently intertemporal evaluation is performed using discounted utilitarian social welfare functions which give utility of future generations less weight than utility of earlier ones. This type of social welfare functions is defined by

$$W(c_1, c_2, \ldots) = \sum_{t=1}^{\infty} \delta_t u(c_t) \tag{4}$$

. In (4) the function $u(c_t)$ again represents utility of consumption and $(\delta_t)_{t=1,2,\ldots}$ is a non-increasing sequence of utility discount factors with $\sum_{t=1}^{\infty} \delta_t < \infty$. These utility discount factors indicate how much utility in period t counts in terms of period 1. Therefore, $\delta_1 = 1$ and, if $\delta_t = 1$ for all $t = 1, 2, \ldots$, undiscounted utilitarianism is obtained as a special case of (4). Traditionally, $(\delta_t)_{t=1,2,...}$ is assumed to fall geometrically, i.e. $\delta_t = \delta^{t-1}$ where $\delta = \frac{1}{1-\rho}$ and $\rho \geq 0$ is the constant discount or time preference rate[3]. Discounted utilitarianism has several desirable properties.

(i) For consumption paths that are strictly bounded away from zero and bounded above social welfare according to (4) is a well-defined scalar such that a complete ordering is obtained. Completeness is an attractive feature if one shares the view that a rational ethical observer should always be able to decide whether one of two arbitrarily given consumption paths is better than the other (or whether they are equivalent). But it may be questioned how important completeness really is, i.e. whether "incompleteness (is) such a defect of an ethical theory" (Roemer J. (2011), p. 370). So if the task is to choose a best element out of a class of technically feasible consumption paths one may be content with finding paths that dominate all other paths for a solely partial ordering, as e.g. the overtaking criterion as conceived by v. Weizsäcker, C. C. (1965) as a specific version of undiscounted utilitarianism. Reducing demands and becoming more modest in this way also reflects the view that it normally is quite unlikely that a single criterion integrates all properties that are normatively desirable. This problem is especially important when there are infinitely many agents/generations such that - since Diamond, P. (1965) - impossibility results abound in the literature on intertemporal evaluation[4]. In particular, it has been shown that a social ordering which fulfils the equal treatment postulate and the strong Pareto principle is not representable by a cardinal social welfare function when there is an infinite number of generations (see Basu, K. and Mitra, T. (2003)). Nevertheless, having a numerical welfare measurement makes the determination of optimal consumption paths simpler and more transparent, which - from a purely technical viewpoint - is a non-negligible advantage of discounted utilitarianism. But properly understood this argument cannot claim much ethical significance.

(ii) Applying a discounted utilitarian criterion is held to be an appropriate safeguard to avoid excessive savings of earlier generations. This is particularly clear if, as in the example of the previous section, we start from a constant consumption path and any generation $t = 2, 3, \ldots$ has an equal increase in consumption ϵ. Then given $\sum_{t=1}^{\infty} \delta_t < \infty$, the level of a welfare-improving investment in period 1 naturally is restricted by $\hat{s} = (\sum_{t=1}^{\infty} \delta_t)\,\epsilon$ which protects generation 1. But, as explained above, along non-constant consumption paths the same effect may also

[3]We emphasize this point, because there is seemingly a remaining confusion of what is being discounted with the discount rate or the discount factor.

[4]One property of social orderings which the literature concentrates on but whose ethical meaning is hard to detect is continuity w.r.t different topologies. See e.g. Svensson, L.-G. (1980), Asheim, G. and Buchholz, W. (2003) and Roemer J. (2011) for a discussion on this. Sakai, T. (2010) instead focuses on the compatibility between anonymity, strong Pareto and transitivity

be brought about with undiscounted social welfare functions. Moreover, if the utility function and the time discount factors are fixed, discounted utilitarianism mitigates but not necessarily avoids excessive savings of the first generation. We will show this using a linear growth model where the capital stock k_{t+1} that generation t hands over to generation $t+1$ is given by $k_{t+1} = \alpha(k_t - c_t)$. Here, α is a productivity parameter which is assumed to be constant over time and which indicates the marginal rate of transformation between consumption in period t and period $t+1$. If k_t is the initially given capital endowment of generation 1 then all consumption paths $(c_1, c_2, \dots)$ are technically feasible for which

$$\sum_{t=1}^{\infty} \frac{c_t}{\alpha_{t-1}} \leq k_1 \tag{5}$$

holds. Just as before we start from a constant consumption path $(\bar{c}, \bar{c}, \dots)$ and assume that generation 1 makes an additional saving of s units of consumption. Then it directly follows from (5) that this enables any subsequent generation to increase its consumption by $(\alpha - 1)s$ units. If we now consider the special case of an isoelastic utility function with $\eta = 1$, i.e. $\ln c$, the sum of discounted utilities flowing from some s is

$$\ln(\bar{c} - s) + \sum_{t=2}^{\infty} \delta^{t-1} \ln(\bar{c} + (\alpha - 1)s) = \ln(\bar{c} - s) + \frac{\delta}{1-\delta} \ln(\bar{c} + (\alpha - 1)s) \tag{6}$$

By an easy calculation the level of savings which maximizes (6) is

$$s^* = \frac{\delta\alpha - 1}{\alpha - 1}\bar{c} \tag{7}$$

For even not quite eccentric values of δ and α, as e.g. $\delta = 0.9$ and $\alpha = 1.25$, (7) implies that generation 1 would be forced to sacrifice 45 % of its initial consumption to make future generations better off. If the productivity parameter α goes to infinity, the level of savings converges to $\delta\bar{c}$ which clearly shows that fixed social preferences will not prevent overburdening of generation 1 in any case, i.e. independent of the underlying technology. Concerning their ability to deal with the danger of excessive saving, the difference between undiscounted and discounted utilitarianism thus turns out to be less fundamental than might appear at first sight.

(iii) The first order conditions along an optimal path in the linear growth model of the previous section are

$$u'(c_{t+1}) = \frac{1}{\delta\alpha} u'(c_t) \tag{8}$$

which for an isoelastic utility function means

$$c_{t+1} = (\delta\alpha)^{\frac{1}{\eta}} c_t. \tag{9}$$

It follows from (9) that the same optimal path is obtained for different combinations of δ and η. In particular, the optimal solution, which results for some originally given parameter values δ and η, can also be implemented without any pure time discount, i.e. $\delta = 1$, by-choosing a different inequality aversion parameter $\tilde{\eta}$ which is

$$\tilde{\eta} = \frac{\eta \ln \alpha}{\ln \alpha + \ln \delta}. \tag{10}$$

This interchangeability of δ and α that, when choices among consumption paths are at stake, the gap between undiscounted and discounted utilitarianism is less deep than usually suspected.

The ethically questionable properties of discounted utilitarianism which more or less mirror the advantages of undiscounted utilitarianism will now be discussed.

(i) Discounted utilitarian social welfare functions do not treat all generations equally as utility of later generations counts less than utility of earlier ones. Thus these criteria violate the basic postulate of intergenerational equity which normally is taken for granted when there only is a finite number of agents.

(ii) It is not excluded that discounted utilitarianism may lead to a non-sustainable development: Along consumption paths that maximize discounted utilitarian welfare (4) consumption of later generations may be smaller than that of earlier ones and, moreover, consumption may go to zero in the long run (see Dasgupta, P. and Heal, G. (1979), p.299). This phenomenon in general occurs if productivity of capital is low as compared to the discount rates. So it immediately follows from (8) that in the linear growth model consumption along an optimal is falling and converges to 0 if $\delta\alpha < 1$. Declining consumption is inevitable for any constant discount factor $\delta < 1$ if, as in the Dasgupta-Heal-Solow model with an exhaustible resource, marginal productivity of man-made capital converges to zero while the utility discount rate ρ is constant over time. Therefore, discounted utilitarianism not only is unfair towards later generations in the light of its assumption but also w.r.t. its possible consequences for the distribution of consumption across generations.

(iii) Discounted utilitarianism may violate the Pigou-Dalton transfer principle. This happens if the transfer goes from a rich early generation t_1 to a poor later generation t_2 whenever $\delta_{t_1} u'(c_{t_1}) > \delta_{t_2} u'(c_{t_2})$. This condition is fulfilled if $\frac{c_{t_2}}{c_{t_1}}$ is close to one but $\frac{\delta_{t_2}}{\delta_{t_1}}$ is rather small.

E. Hybrid Criteria

In the recent literature on intertemporal evaluation a lot of suggestions for new criteria have been made to overcome some of the deficiencies of the standard criteria. The conceptually simplest approach is to combine two criteria in order to preserve some of the advantages of both. Modifying an approach of Chichilnisky, G. (1996), **?** have suggested some composition of discounted utilitarianism with the maximin rule such that

$$W(c_1, c_2, \dots) = (1 - \Theta) \sum_{t=1}^{\infty} \delta_t u(c_t) + \Theta \inf_{t=1,2,\dots} u(c_t) \tag{11}$$

emerges as *mixed* Bentham-Rawls welfare function. Here, the right-hand side of the equation is referring here to utilities and the parameter Θ indicates the relative weight which the maximin has in the aggregate criterion. Applying a welfare function of this type gives a complete ranking of consumption streams and, above all, makes less likely that early generations enjoy a large increase in their well-being but the great many of future generations are driven into poverty. Thus a major possible shortcoming of discounted utilitarianism can be avoided and more equitable balance of interest between the present and the future is achieved. But a sustainable development is not ensured in any case just if the parameter Θ is very small (see **?**), and the strong Pareto criterion is only fulfilled if the utility function $u(c)$ is bounded below. This, however, is not an innocuous assumption since in most empirical applications isoelastic utility functions $u(c)$ with inequality aversion $\eta \geq 1$ and thus $\lim_{c \to 0} u(c) = -\infty$ are used (see also the subsequent Section 3 for a justification of this). Moreover, if $\delta < 1$, the social welfare function does not imply equal treatment of all generation such that anonymity as the basic postulate of intergenerational equity is also violated with mixed Bentham-Rawls criteria.

In contrast to that Zuber, S. and G. Asheim (2010) have devised a new criterion which combines anonymity with discounting. The idea underlying this approach is that discounting does not depend on the period of time in which some level of consumption accrues but on the rank which the consumption level of a generation has in the whole consumption path. A problem with this rank-discounted utilitarianism is that, given an infinite number of generations, a ranking of consumption levels does not exist for all consumption streams, e.g. for any strictly decreasing path, such that additional constructions are required to extend and complete the social ordering, and strong Pareto. Nevertheless, rank-discounted utilitarianism gives later generations much more protection against rapacity of the earlier ones than the mixed Bentham-Rawls welfare functions which, from the perspective of sustainability, constitutes an important advantage. With the Asheim-Zuber criterion serves as an "added expression of aversion to inequality" (Asheim, G. (2011), p. 8). But some further discussion seems to be advisable why rank-discounted utilitarianism should in this respect be considered superior to undiscounted utilitarianism.

Rejecting the utilitarian framework at all Llavador, H., Silvestre, J. and J. Roemer (2008) have devised a new type of criteria in which an exogenously given constant growth rate g of well-being is the objective that optimal paths have to fulfill. Proceeding in this unconventional way the maximin rule (where $g = 0$) is generalized to a sustainable growth criterion which allows for economic progress and which thus cures the major defect of pure maximin. The question, however, is through which normative concepts the choice of some growth target g may be motivated. Moreover, in some technological environments as the standard Dasgupta-Heal-Solow model, consumption growth with any constant positive rate is not possible which somewhat reduces the applicability of the Llavador-Silvestre-Roemer criterion.

F. Some Preliminary Assessment

All intertemporal social welfare functions that we have discussed have their pros and cons. Since maximin - with its exclusion of investment and economic progress - mostly deserves attention for fixing basic ideas the real choice is between undiscounted and discounted utilitarianism. Which of these criteria is to be preferred thus is the major field of controversy in the scientific debate. Until now we have only compared these two types of evaluation criteria at an abstract level without saying anything about the parameter values that are needed to specify them. In particular, a decision on the appropriate level of the degree of inequality aversion η incorporated in the isoelastic utility function $u(c)$ and the discount rate ρ are required to make the criteria applicable.

In simulation studies on climate change policy (as e.g. in Nordhaus' DICE-model) η and δ are, in the tradition of the descriptive school, normally determined by calibrating numerical growth models such that the Ramsey equation $r = \eta g + \delta$ (see e.g. Dasgupta, P. and Heal, G. (1979) or Stern, N. (2006)) is fulfilled for the empirically observed consumption growth rate g and the real interest rate r. Proceeding this way (**?**, p. 692) finds "the ethical reasoning on discount rates (...) largely irrelevant for the actual investments and negotiations about climate change". But from the viewpoint of the prescriptive school adopted here the parameter choice should also be made on the basis of normative principles. What at least is required "is adjusting certain parameters so as to reach a conclusion more in line wit our intuitive judgments" (Rawls, J. (1971), p. 298).The possibility to determine these parameters by ethical reflections may also have some repercussions for the acceptability of the criteria as such. These additional, and in contrast to the topics treated until now, less familiar ethical issues will now be discussed.

III. CHOICE OF PARAMETERS FROM A NORMATIVE PERSPECTIVE

The degree of inequality aversion of the utility function plays a role for the specification of undiscounted, discounted and the hybrid criteria discussed above. The pattern of the time discount rate is only important for discounted utilitarianism and the hybrid versions. In the case of the mixed Bentham-Rawls criteria the weighing factor for the maximin part would have to be determined in addition.

A. Inequality Aversion

The Stern Review on the Economics of Climate Change (see Stern, N. (2006)), in contrast to much previous work on climate change, explicitly addressed the ethical dimension of intergenerational evaluation which in particular meant that it in principle adopted the equal treatment postulate for generations deeply rooted in the prescriptive school. Therefore, in Stern's approach the elasticity of marginal utility η automatically became the main tool for bringing about an ethically acceptable balance of interest between different generations. But, somewhat surprisingly, the highly crucial choice of η was not discussed explicitly from the ethical viewpoint. In this context the reflections remained rather scanty, and no convincing normative justification for specifically choosing as inequality aversion index in the main part of the empirical study was given. At the central place of the Report (see Stern, N. (2006), p. 184) there is only a short remark that employing $\eta = 1$ is "in line with recent empirical estimates". Reference, however, only is made to two empirical papers by Stern, N. (1977) and Pearce, D. and D. Ulph (1995), and it is not explained why such empirical estimates might at all be of much value for making ethical decisions. So coming to the choice of η , Stern, N. (2006) does not contribute very much and, to some degree, even neglects his ethical intentions. The discussion after Stern, N. (2006), however, has shown that ethically relevant arguments on the choice of η can be found in three different ways.

(i) Adopting an ethical perspective does not exclude that the ethical values of existing people become the standard of evaluation. Then the debate is not about what seems to be just in the eyes of an impartial and detached ethical observer but which altruistic attitudes are prevalent in a society. This approach, on which - without any further explanation and assessment - Stern, N. (2006) draws on, combines prescriptive and descriptive elements but observed data do not come from the market-place but from political decisions where ethical motivations on distributional issues manifest. Although many political decisions (e.g. on pension reform and the size of the government deficit) clearly affect distribution between generations, it is very difficult, if not impossible to find out the level of underlying inequality aversion η. Therefore, results on individual preferences for redistribution that are obtained from empirical studies on the income tax system are transferred to the field of intergenerational distribution. The various studies on inequality aversion as expressed by income tax progressivity give quite different values for η which in some studies lies in the interval be-tween 1 and 2 (see Evans, D. (2005)) but is lower in other studies (see Atkinson, A. and Brandolini, A. (2010)). These data certainly give some hint at existing normative beliefs on inequality. But the attitudes towards income distribution within a society are multi-dimensional and include aspects of effort and merit which are absent in the intergenerational context (where instead motivations as responsibility and stewardship play some role). So it may be doubted whether the estimates for that have been obtained from income tax studies can easily be applied to intergenerational evaluation and climate policy.

(ii)The ethical acceptability of different values of η can also be assessed by conducting "thought experiments" through which their implications in specific theoretical models are described and, in the end, some "reflective equilibrium" (see at a general level Rawls, J. (1971) and with specific application to intergenerational equity Asheim, G. (2010)) on distributional norms might be achieved. In this vein Dasgupta, P. (2008) has examined which consequences the choice of η as suggested by Stern, N. (2006) has for the speed of optimal growth in a linear Ramsey growth model. Under otherwise plausible assumptions the essentially well-known result was that $\eta = 1$ would lead to an extremely high savings rate along optimal growth paths amounting to almost 100 %. Then a fair balance of intergenerational distribution would not be attained since the early generations suffers very much from the consumption sacrifices that are imposed on them to make the future better off. In this way the traditional oversaving argument that usually is applied to disprove undiscounted utilitarianism is brought into play to make judgments about sensible values of η. Following this approach instead of $\eta = 1$ higher levels of η (e.g. $\eta = 2$ as proposed by Dasgupta, P. (2008) and other authors like Weitzman, M. (2007)) are warranted, which lead to more equal optimal consumption paths and protect earlier generations from overburdening through excessive saving.

(iii) It is also possible to start from some explicitly formulated postulates (or "axioms") which a social welfare function should fulfill. Such a property is "circumstance solidarity" (Fleurbaey, M. (2008)) which in the context of growth theory means that no generation should lose in an optimal allocation when the technological conditions improve, i.e. in a linear growth model the productivity parameters are increased. If this condition is to be satisfied all values $\eta < 1$ are excluded (see Buchholz, W. and Schumacher, J. (2010)). Therefore, $\eta = 1$ as predominantly used in Stern, N. (2006), turns out to be the minimum degree of inequality aversion, which seems to be acceptable if circumstance solidarity is adopted as a normative postulate. In the framework of such an axiomatic approach one can add other ethical postulates, as e.g. non-envy criteria which are also familiar in ethical social choice theory. With this approach $\eta = 1$ results when the non-envy condition refers to the *absolute* consumption levels of different generations. Alternatively, we get $\eta = 2$ when non-envy comparison between generations refers to *relative* consumption levels (for details see again Buchholz, W. and Schumacher, J. (2010)).

Different values of η reflect value judgments, either at the level of voters or at the level of an ethical observer. These value judgments unavoidably have a subjective element so that it is clear from the very beginning that one cannot expect to obtain a unique and uncontroversial estimate for η. In spite of this general caveat, several theoretical exercises as conducted above support the view that low inequality aversion with values $\eta < 1$ will not conform to ethical intuition. Recent empirical observations on revealed ethical preference in tax policy are not in contrast to this lower bound as most of them suggest values for η somewhere between 1 and 2. Therefore, we can conclude that from an ethical perspective Stern, N. (2006) works with an extremely low degree of inequality aversion thus implicitly giving the future (too) much weight.

Concerning an upper bound for η , things are less clear. No one in the debate seems to advocate a value of η much higher than 3. But these proposals mostly follow from pure guesswork such that additional research which aims at finding more precise foundations for such choices seems to be required.

B. Time Preference

Determination of pure utility time discount factors $(\delta_t)_{t=1,2,...}$ is still less straightforward than of inequality aversion η. There are three approaches which - similar as in the case of η - either refer to stated preferences of individuals or to normative ideas of an ethical observer.

(i) Aggregating opinions of more than 2000 economists Weitzman, M. (2001) obtained discount rates not being constant but falling to zero over time. Specifically, he got a discount rate of 4 % for the next 5 years as the "immediate future", then 3 % until year 25 from now, 2 % between year 26 and 75, 1 % between year 76 and 300 and thereafter for the "far-distant future" the discount rate is 0. But as Weitzman's study had the character of a black box and the motives of the respondents have not been explored systematically, it is not clear what the elicited discount rates really express. In particular, it is left open whether the answers reflect pure time preference as such or whether the results are confounded by other aspects as inequality aversion or predictions of future growth rates. These difficulties, which occur if one tries to isolate pure time preference as a behavioral motive, are well-known from the empirical literature on discounting as a determinant of individual choices in every-day life. Controlling for these additional factors normally leads to discount rates that are substantially lower than those originally suspected (see Frederick, S., Loewenstein, G. and O´Donoghue, T. (2002)). Another difficulty with Weitzman's approach is related to the specific method he uses to aggregate the elicited time discount rates. For an illustration of this problem we consider a simple example, in which there are two respondents a and b. Agent a has the constant time preference rate $\rho^a = 0$ such that for the time discount factors of this agent $\delta_t^a = 1$ holds for all periods $t = 1, 2, \ldots$. Agent b instead has the time preference rate $\rho^b = 1$ such that $\delta_t^b = \left(\frac{1}{2}\right)^{t-1}$ in period t. Taking the average of these both discount factors gives

$$\delta_t^m = \frac{1}{2} \cdot 1 + \frac{1}{2} \cdot \left(\frac{1}{2}\right)^{t-1} \tag{12}$$

as discount factor for period $t = 1, 2, \ldots$. Clearly, $\lim_{t\to\infty} \delta_t^m = 1$ which means that the discount rates obtained by this averaging procedure must converge to 0 in the long run. The same result holds when there are not different opinions on time preference but when discount rates are uncertain (Weitzman, M. (1998)). This theoretical exercise shows that Weitzman's main result, i.e. that costs and benefits should be discounted at the lowest possible rate, does not so much rest upon the collected opinions on the discount rate but rather is a direct consequence of his aggregation method which is not at all naturally given. So, alternatively, one could simply average the different stated discount rates, which based on Weitzman's data would give the constant discount rate of about 4 % , or consider - as suggested by Gollier, C. (2004) - the average value of *future* instead of present values, which would change the outcome totally. Then the far-distant future would have to be discounted at the highest possible rate. In any case it is required that the ideas, and possibly their normative content, lying behind the aggregation method is explained and motivated carefully. Otherwise, the procedure remains ad hoc and its results only have restricted value.

(ii) Assume that the ethical observer is behind a veil of uncertainty and then applies expected utility theory. If the different states of the world will not occur with the same probability she will take these differences into account when she makes her assessment - even if, in principle, she is impartial and does not favor any position. In the intergenerational context this argument implies that it is ethically well acceptable to give later generations some lower weight in social evaluation since there is some risk that mankind (e.g. by an asteroid or by a devastating epidemic disease) may be extinct and thus later generations that can enjoy the fruits of savings today do not exist. If this risk of extinction from one period to the next is assumed to be constant over time and equal to π the discount factor in period t is equal to the probability of survival $\delta_t = (1-\pi)^{t-1}$. Estimation of clearly is very speculative and a matter of subjective belief. In particular, Stern, N. (2006) has assumed a probability of 10 % that civilization may be extinct within one century which implies an annual utility discount rate $\rho = 0.1\$$. From the ethical standpoint it may also seem questionable to make such a bet on the existence of future generations.

(iii) If we return to the linear growth model and especially to equation (x) it becomes clear that non-decreasing and thus sustainable consumption paths emerge as optimal solutions if $\delta\alpha > 1$, i.e. $\delta > \frac{1}{\alpha}$ or $\rho < \alpha - 1$, which means that the time discount rate must be lower than the economy's net productivity. Growth of consumption along an optimal path becomes slower if inequality aversion η is increased. If $\delta = \frac{1}{\alpha}$ or $\rho = \alpha - 1$ a constant consumption path is obtained. With this approach the time discount rates which are considered as appropriate vary with the underlying technology and thus become endogenous. The ethical primitive then is some desirable speed of growth which is well in line with Rawls, J. (1971) "just savings principle" and his justification of pure time discount. A problem with this approach, however, is that the familiar idea that time discount rates are part of fixed social preferences, which exist independent of the technological conditions, has to be abandoned. But at least some upper bound for the admissible discount rate is found by which a non-sustainable development can be avoided.

IV. CONCLUSION

If the choice of a specific intertemporal evaluation criterion is seen to be an ethical one, which is the viewpoint adopted in this article, an undisputable solution clearly does not exist. Following M. Weber's famous "Wertfreiheitspostulat" it can never be decided objectively and on a scientific base what should be considered as an equitable distribution e.g. among generations. Nevertheless, our considerations allow some tentative conclusions.

(i) Concerning the decision between undiscounted and discounted utilitarianism turning down the undiscounted version as often postulated in the literature neither seems to be appropriate nor necessary. On the one hand, undiscounted utilitarianism implies equal treatment of all generations and ensures sustainability, which are attractive properties of evaluation criteria. On the other hand, it does not seriously restrict the possibility to make choices among increasing consumption paths such that, in particular, the introduction of pure time discount is not really required to avoid the problem of excessive saving which usually is attributed to undiscounted utilitarianism and is seen as one of its major shortcom-

ings. To endorse equal treatment of generations and thus undiscounted utilitarianism at the fundamental level does, moreover, not preclude that some, possibly extremely small pure time discount rate is applied through which the uncertainty of future costs and benefits is taken into account. Irrespective of the chosen level of the time discount rate such a kind of "discounted utilitarianism light" in particular gives numerical representability of the underlying social ordering what, on the one hand, faciliates application to empirical cost-benefit analysis. On the other hand, it ensures completeness of the social ordering and fulfillment of the strong Pareto principle such that the extensive theoretical discussion on impossibility results in the infinity case becomes a little redundant. Seen from such a pragmatic perspective also some doubts may arise whether the more complicated hybrid criteria really make an improvement. So, partly for the same and partly for additional reasons as drawn on by Stern, N. (2006), we are essentially backing Stern's approach to intertemporal evaluation which, at a general level, might represent shift of paradigm in intertemporal evaluation.
(ii) Concerning the parameters that specify the social welfare function we also accept Stern's choice of a very low pure time discount rate ρ but reject his choice of the inequality aversion parameter η as too low. Various thought experiments conducted in growth theoretic models as well as empirical observations of actual political decisions on redistribution suggest values of η that are higher than 1 and mostly lie closer to 2 than to 1. By now, unfortunately, no clear-cut normative criteria seem to be available which might help to determine more precise value for η. Thus there is much room left for the choice of η , such that in specific applications robustness tests with different values of η are advisable. But, as a practical consequence, employing some higher level of η gives less weight to the future which, in the context of climate policy, means that the abatement of greenhouse gas emissions could happen more slowly than suggested by Stern, N. (2006). Then, working with more sensible values of η, would take much edge off the partly very heated debate on the Stern Report and its urgent demand for strong and immediate action in climate change policy. In a certain way, this confirms a basic message of this paper: The question of principle whether to use undiscounted or discounted utilitarianism is to some degree futile concerning practical policy implications. What in the end matters much more is the selection of specific parameter values for which some well-founded ethical judgment, however, is often hard to provide.

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