Discounting and welfare analysis over time: Choosing the η

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May 18, 2009

Abstract

Based on the Ramsey equation and the rejection of pure utility time discount, the Stern Review on the Economics of Climate Change concentrates on the use of the elasticity of marginal utility η in the intergenerational social welfare function (and not on the pure rate of time preference ρ as most of the existing literature) in order to avoid excessive saving. In this paper we first show that also from the viewpoint of sustainability, it is preferable to make ethically motivated decisions on the distribution across generations by the use of η and not of ρ. In addition, we examine how different specific values of η correspond to ethically relevant properties as "circumstance solidarity" and "no–envy". Finally, we discuss the fundamental critique that has been raised against Stern's ethically based welfare–theoretic approach to valuation across time.

Keywords: Ramsey equation, discounting, sustainability, circumstance solidarity, no–envy

JEL-Code: D6, D9, Q5

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We thank Ted Bergstrom, Richard Cornes, Jürgen Jerger, Kai Konrad, Mariusz K. Krawczyk, Wolfram Richter, Hans–Werner Sinn, Rolf Tschernig, Ulrich van Suntum and participants of the Research Seminar at the University of Regensburg, of the CESifo conference on Ethics and Economics (February 2008), of the IIPF annual meeting at Maastricht (August 2008) and of the annual meeting of the Verein für Socialpolitik at Graz (September 2008) for helpful comments and Andreas Graichen for carefully reading the manuscript. Suggestions of an anonymous referee and the two editors of this volume, Manfred Holler and Vesa Kanniainen, helped to improve the paper considerably. The usual disclaimer applies.

1 Introduction

The evaluation of consumption– and utility–streams over time by means of discounted utilitarian objective functions has been a main topic in economics for a long time. The most important questions that economists have discussed in this context are: How should the social discount rate used in intertemporal cost–benefit–analysis be related to market interest rates? How should uncertainty be taken into account? Is discounting of costs and benefits justified at all when future generations are involved? The publication of the "Stern Review on the Economics of Climate Change" (Stern (2006)) has revitalized this ongoing debate on discounting which even got some broader publicity that way (see e.g. The Economist (2006) or Varian (2006) in the New York Times). This is not surprising since the design of climate policy measures crucially depends on the level of the underlying social discount rate. The emission and abatement of greenhouse gases as, above all, CO_2 has very long run consequences reaching over many centuries such that even small changes of the discount rate exert considerable impact on aggregate benefits and costs.

In the Stern Report the discount rate r is determined through the *Ramsey equation* of optimal growth (Ramsey (1928)), which in Stern's welfare theoretic approach (see Stern (2006), pp. 41-54, for a clearer description) is applied to the perspective of a fictitious social planner or "ethical observer" who seeks to maximize welfare over time.[1] As a general condition for optimality of growth paths it links the consumption discount rate $r(t)$ at some point of time t to the utility discount rate ρ (which is mostly assumed to be time invariant), to the elasticity η of the planner's marginal utility of consumption (given some iso–elastic utility function) and to the consumption growth rate $g(t) = \frac{\dot{c}(t)}{c(t)}$. Omitting the time variable t, the Ramsey rule explicitly reads as follows:

$$r = g\eta + \rho \tag{1}$$

Putting equation (1) into the focus of the treatment of discounting is very helpful to clarify two issues. First of all, this equation indicates that a clear distinction must be made between the *utility* discount rate ρ and the *consumption* discount rate r. Whereas the utility discount rate ρ is exogenously given as a parameter of pure time preference, the consumption discount rate r is determined endogenously along the path that – for given $\rho > 0$ – maximizes the present value of aggregate discounted utility. But the Ramsey equation also presents a still more fundamental insight on discounting in a compact way: Having in mind that the purpose of discounting is to find a balance between present and future welfare, the Ramsey equation shows that, to this end, a positive pure utility time discount rate ρ can, to some extent, be substituted by a sufficiently high elasticity of marginal utility η. This idea has a very long tradition in the theory of interest, dating back already to Böhm–Bawerk (1891), and was taken up, later on, e.g. by Dasgupta & Heal (1979), Olson & Bailey (1981), Sinn (1987), Dasgupta (2001) and Asheim & Buchholz (2003).

In the extreme, the Ramsey equation would be fulfilled by setting $\bar{\eta} = \frac{r}{g}$ even if the utility discount rate is zero, i.e. $\rho = 0$. Having no pure time discount of utility seems

[1]See, e.g. Mas-Colell et al. (1995), pp. 825–838, for a general description of the welfare theoretic approach, and w.r.t. intergenerational allocation Dasgupta & Heal (1979), pp. 258–265. Note, however, that the welfare maximization over time, and thus the Ramsey rule, may also be applied to individual decisions, either assuming agents with infinite lives or altruism towards the chain of offsprings (see, e.g., Romer (2006)). There is a deep conceptual distinction between the ethical and the individualistic approach which is often not clarified. See Atkinson (2001) for a succinct discussion on that.

particularly appealing when evaluation over time extends to future generations. Otherwise, with $\rho > 0$, the underlying intertemporal preferences would not be intergenerationally neutral which seems to be ethically questionable.[2] From this viewpoint, avoiding pure time discount and relying instead on the parameter η is preferable, because in this way systematic discrimination against people that unluckily appear later on the time axis will not occur. The Stern Review essentially shares this ethical point of view by applying a very small positive $\rho = 0,001$ only to capture the small risk that the human species might be extinct (e. g. by an asteroid or so).[3] Concerning the normative foundation of intertemporal evaluation, the Report and its critics consequently concentrate on the choice of η which, with this rigor, has not been quite common in intertemporal welfare economics until recently. In this paper, we follow this approach, and explore somewhat further the use of η as a determinant of intertemporal allocation.

In our paper, we will proceed as follows: In order to make the basic relationships as transparent as possible, we explain, in Section 2, the interchangeability of ρ and η in a simple two–generations–model. In particular, we show that invoking "sustainability" as a commonly shared postulate gives an additional justification for making intertemporal decisions by η and not by ρ. In Section 3, we then compare different empirical studies that try to determine reasonable values of η and assess their relevance in the intergenerational and ethical context. In Section 4 we explore, through some novel thought experiments, which specific values of η correspond to normatively appealing properties, such as "circumstance solidarity between generations" and "no–envy". In Section 5 we discuss some of the critical comments raised against Stern's ethically motivated approach and in particular its preference of η over ρ and hint at its limitations.

2 Intertemporal choice in a two–period–setting

2.1 The classical argument in favor of pure time discount

Assume that in a world of full certainty, there are two generations $t = 1, 2$ of equal size, and that their consumption is given by c_t, respectively.[4] By $G(c_1, c_2) = g$ we denote the transformation curve, where $G(c_1, c_2)$ is a partially differentiable and quasi–convex function, which we assume to be strictly increasing in both variables, thus leading to a strictly decreasing and concave transformation curve in the c_1–c_2–space. Generation t's well–being (in the classical utilitarian sense) is denoted by $u_t = u(c_t)$. The equality consciousness of a hypothetical social planner (the "ethical observer") is described by a (twice differentiable) *evaluation function* $h(u_t)$ with $h'(u_t) > 0$ and $h''(u_t) < 0$. Defining $\delta = \frac{1}{1+\rho}$ as the *discount factor* when $\rho \geq 0$ is the pure rate of time preference, the intertemporal social welfare function becomes

$$W(c_1, c_2) = h(u(c_1)) + \delta h(u(c_2)) \tag{2}$$

The social planner then maximizes $W(c_1, c_2)$ with $G(c_1, c_2) = g$ as the side constraint. Omitting variables, the first order condition for an interior solution of this maximization problem is given by

$$\pi \cdot \mu = \delta \cdot \gamma. \tag{3}$$

[2]Unequal treatment of generations has also been objected by many economists. See, e.g. Ramsey (1928), Pigou (1932), and Harrod (1948), all quoted in the Stern Review.

[3]For a review of the philosophical discussion on pure time discount see, e.g., Broome (1994) and Broome (2004).

[4]See Olson & Bailey (1981), Buchholz (2003) and Creedy (2006) for such an elementary treatment.

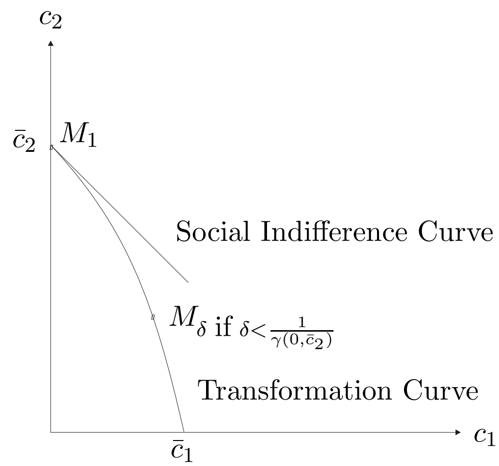

Figure 1: Excessive saving without utility discounting and inequality aversion.

Here $\pi(u_1, u_2) := \frac{h'(u_1)}{h'(u_2)}$ and $\mu(c_1, c_2) := \frac{u'(c_1)}{u'(c_2)}$ are the relevant *marginal rates of substitution* of the social planner and the individuals, respectively, given $h(u)$ and $u(c)$, and $\gamma := \frac{\partial G/\partial c_1}{\partial G/\partial c_2}(c_1, c_2)$ is the *marginal rate of transformation* between consumption of generation 1 and generation 2 at some (c_1, c_2).

Using condition (3) a standard argument in favor of pure time discounting, i.e. $\rho > 0$ and thus $\delta < 1$, can be illustrated by an extreme example: Assume that the economy is *productive* such that making a sacrifice of one unit of consumption in period 1 will increase consumption by more than one unit in period 2. In this case, $\gamma(c_1, c_2) > 1$ holds for all (c_1, c_2) on the transformation curve and $(\gamma(c_1, c_2) - 1)$ gives the (marginal) internal rate of return which is the "remuneration" for waiting. Furthermore, suppose that the agents' utility function $u(c_t)$ shows constant marginal utility (which implies $\mu = 1$), that the central planner exhibits no inequality aversion (which means $h(u_t) = u_t$ and thus $\pi = 1$) and furthermore wants to treat both generations equally (i.e. $\delta = 1$). Then clearly, condition (3) cannot be fulfilled as in this case for all points along the transformation curve we have

$$\pi \cdot \mu = 1 \cdot 1 < 1 \cdot \gamma = \delta \cdot \gamma \tag{4}$$

Then the welfare maximum is a corner solution in which generation 1 has zero consumption or, equivalently, the savings rate is 100%. This situation is depicted in Figure 1 where the optimal allocation M_1 lies on the vertical axis.

In a productive economy unfettered utilitarianism with equal treatment of both generations, i.e. application of the welfare function $W(c_1, c_2) = c_1 + c_2$, thus implies a strong bias against the earlier generation and renders the socially optimal allocation extremely unequal.[5] Because the economy is productive, aggregate consumption only becomes max-

[5]The excessive sacrifice argument can also be related to Böhm-Bawerk's (1891) third reason for a positive interest rate (see already Buchholz (2003)): "For if every employment of goods for future periods is, not only technically, but also economically, more remunerative than the employment of them for the present and near future, of course men would withdraw their stocks of goods, to a great extent from the service of the present, and direct them to the more remunerative service of the future. But this would cause an ebb-tide in the provision of the present, and a flood in the provision of the future" (Böhm-Bawerk (1891), pp. 269-270). For a nice presentation of the same idea also see Broome (2006). Böhm-Bawerk's first reason is, roughly speaking, captured by η and his second reason by ρ.

imal if the whole consumption is postponed to period 2, forcing generation 1 into a state of poverty. In an infinite generation setting the "jam tomorrow" paradox arises, i.e. there would be an incentive for the social planner to delay consumption forever, which technically means that welfare maximization has no solution at all. See, e.g., Koopmans (1960).

The earlier generation 1 can be protected against such excessive saving by introducing sufficiently high positive rates of time preference $\rho > 0$. As soon as $\delta < \frac{1}{\gamma(0,\bar{c}_2)}$ the earlier generation will enjoy a strictly positive consumption level in the optimum M_δ. Consumption of generation 1 becomes higher and that of generation 2 becomes lower if ρ increases and, consequently, δ decreases. Achieving a more equal intertemporal distribution of consumption in this way is a classical justification for discounting in the intertemporal social welfare function.[6]

2.2 The interchangeability between ρ and η

A safeguard for the earlier generation can, however, not only be provided by pure time discount, but also by decreasing marginal utility of consumption $u''(c_t) < 0$ at the agent's level and/or by having inequality aversion $h''(u_t) < 0$ at the level of the social planner. Being interested in *ethical criteria* underlying *social evaluation* we concentrate our attention on the second possibility, i.e. on the planner's evaluation function $h(u_t)$.[7] For the sake of simplicity we thus suppose $u(c_t) = c_t$ and, furthermore, that the transformation function $h(u_t) = h(c_t)$ of the social planner is isoelastic, i.e. has the form

$$h(c_t) = \begin{cases} \frac{c_t^{1-\eta}}{1-\eta} & \text{for } \eta \in]0, \infty[, \eta \neq 1 \\ ln\, c_t & \text{for } \eta = 1 \end{cases} \tag{5}$$

where η, as the elasticity of the planner's marginal valuation of individual utility/consumption, indicates his degree of inequality aversion (as in Atkinson's (1970) classical approach to inequality measurement). The results of this chapter could, in principle, also be obtained by assuming $h(u_t) = u_t$ and an iso–elastic utility function $u(c_t)$ at the individual level. But note that this is a purely formal analogy since with this alternative interpretation δ and η would be parameters that characterize individual preferences. In the Stern Review, as in most other contributions to intergenerational discounting, δ and η are ethical parameters, and, as in our paper, individual utility functions are on purpose assumed to be linear in consumption for matters of tractability.

Having again $\delta = \frac{1}{1+\rho}$, the social welfare function which applies to our two–generations framework is

$$W_{\eta,\delta}(c_1, c_2) = \begin{cases} \frac{c_1^{1-\eta}}{1-\eta} + \delta \frac{c_2^{1-\eta}}{1-\eta} & \text{if } \eta \in]0, \infty[, \eta \neq 1 \\ ln\, c_1 + \delta ln\, c_2 & \text{if } \eta = 1 \\ min\{c_1, c_2\} & \text{if } \eta = \infty \end{cases} \tag{6}$$

The case $\eta = \infty$ is obtained in the limit if η goes to infinity (see, e.g., Mas-Colell et al. (1995), p. 829, for details.) Having $\eta < \infty$, the marginal condition (3) is fulfilled for some consumption profile $(\tilde{c}_1, \tilde{c}_2)$ if

$$\left(\frac{\tilde{c}_2}{\tilde{c}_1}\right)^\eta = \delta\gamma\left(\tilde{c}_1, \tilde{c}_2\right) \tag{7}$$

[6] This argument in favor of pure time preference has been put forward by both philosophers (e.g. Rawls (1971)) and economists (e.g. Arrow (1999)). See Marini & Scaramozzino (2000) for a theoretical analysis and Hepburn (2006*a*) for an extensive discussion of the excessive sacrifice argument.

[7] This corresponds to the approach chosen by most contributions to this debate.

which gives a simple analogue of the Ramsey equation in the two–period–model.[8] If η approaches infinity and δ is fixed, the optimal solution according to (7) converges to that with equal consumption for both generations.

We now want to ask which social welfare functions $W_{\eta,\delta}(c_1, c_2)$ have properties that are appealing from a normative point of view.[9] From (7) it is immediately obvious that the same allocation $(\tilde{c}_1, \tilde{c}_2)$ is obtained as the welfare–maximizing solution for different combinations of ρ and η. In order to describe this substitutability between the two parameters in more detail, we take logarithms of (7) and let $\delta^*(\tilde{c}_1, \tilde{c}_2) := \frac{1}{\gamma(\tilde{c}_1, \tilde{c}_2)}$. For $\tilde{c}_1 \neq \tilde{c}_2$, this yields

$$\eta(\delta) = \frac{ln\,\delta - ln\,\delta^*(\tilde{c}_1, \tilde{c}_2)}{ln\,\tilde{c}_2 - ln\,\tilde{c}_1} \tag{8}$$

For an interpretation of (8), we distinguish three cases:

Case 1: $\tilde{c}_2 > \tilde{c}_1$, i.e. $ln\left(\frac{\tilde{c}_2}{\tilde{c}_1}\right) > 0$. Then $\delta \geq \delta^*(\tilde{c}_1, \tilde{c}_2)$ is required. In this range, a higher δ can be replaced by a higher η. (See Figure 2.)

Case 2: $\tilde{c}_2 < \tilde{c}_1$, i.e. $ln\left(\frac{\tilde{c}_2}{\tilde{c}_1}\right) < 0$. Then $\delta \leq \delta^*(\tilde{c}_1, \tilde{c}_2)$ is required. In this range, a higher δ can be substituted by a lower η. (See Figure 3.)

Constant consumption paths can be included as follows:

Case 3: $\tilde{c}_2 = \tilde{c}_1$, i.e. $ln\left(\frac{\tilde{c}_2}{\tilde{c}_1}\right) = 0$. For any $\eta < \infty$, δ is uniquely determined as $\delta = \delta^*(\tilde{c}_1, \tilde{c}_2)$. If, however, $\eta = \infty$ and $\delta > 1$ gives the solution with $\tilde{c}_2 = \tilde{c}_1$.

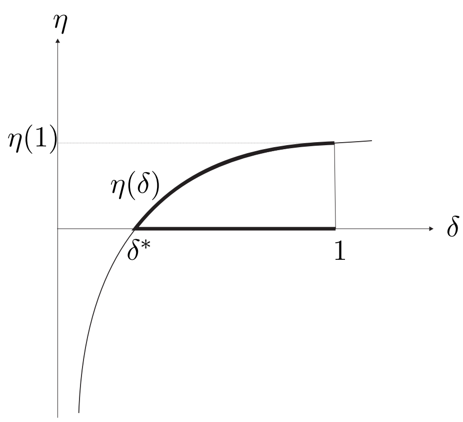

Figure 2: Case 1: $\tilde{c}_2 > \tilde{c}_1$

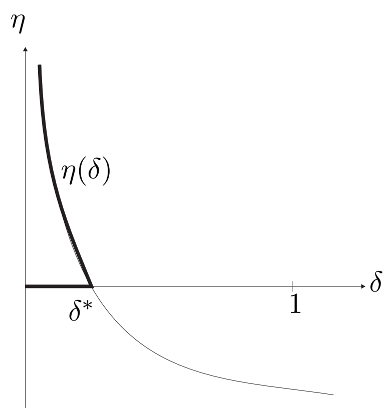

Figure 3: Case 2: $\tilde{c}_2 < \tilde{c}_1$

In Figures 2 and 3 the solid lines describe the combinations of δ and η that all yield the allocation $(\tilde{c}_1, \tilde{c}_2)$. In particular we look at the both extreme cases with either $\eta = 0$

[8]It is, however, a rather complicated exercise to derive the Ramsey equation from (7). See Dasgupta (2001), p. 18, and Creedy (2006).

[9]This agenda has already been put forward in a very succinct way by Dasgupta & Heal (1979), p. 260, where they, with reference to social welfare functions, write: "The question arises: how are the conflicting needs of different generations to be weighed and balanced off against on another...? Quite obviously, there can be no resolution to this problem. What one can do though is to articulate in a precise manner the various considerations that may appear morally relevant in answering it."

(no inequality aversion) or $\delta = 1$ (no pure time discount): If $\eta = 0$ *every* consumption profile $(\tilde{c}_1, \tilde{c}_2)$ on the transformation curve becomes a welfare maximum by letting $\delta = \delta^*(\tilde{c}_1, \tilde{c}_2) < 1$. If, however, $\delta = 1$ is assumed, only paths $(\tilde{c}_1, \tilde{c}_2)$ that have $\tilde{c}_2 > \tilde{c}_1$ are – by letting $\eta = \eta(1)$ – obtained as welfare maximizing solutions (compare Figures 2 and 3). Thus, there is an asymmetry between Case 1 and Case 2. In particular, making choices between consumption paths through δ instead of η gives more flexibility. But this does not necessarily seem to be an advantage if *sustainability* as a further and commonly shared normative postulate is invoked. According to the usual definitions, economic development is called 'sustainable' if consumption or utility does not deteriorate over time.[10] Otherwise, there would be no economic progress and, metaphorically speaking, earlier generations could be accused of living at the expense of their descendants. In our simple two–generations–model non–decreasing and thus sustainable paths $(\tilde{c}_1, \tilde{c}_2)$ lie on the segment BC in Figure 4. Then our previous treatment of the case without pure time discount, i.e. $\delta = 1$, gives then the following result:

Proposition 1 Let $\delta = 1$. A consumption path $(\tilde{c}_1, \tilde{c}_2)$ is sustainable, i.e. $\tilde{c}_2 \geq \tilde{c}_1$, if and only if it is a welfare maximum for some social welfare function $W_{\eta,1}(c_1, c_2)$ where $\eta \in]0, \infty]$.

This proposition says that, with equal treatment of both generations, on the one hand only non–decreasing consumption paths are selected by $W_{\eta,1}(c_1, c_2)$, irrespective of the size of η. On the other hand, the social planner can pick any sustainable path by an adequate choice of η and simultaneously fixing $\delta = 1$. Specifically, for the selection of constant consumption paths with $\tilde{c}_2 = \tilde{c}_1$ one has to use $\eta = \infty$.

So for making choices among sustainable paths it is possible to do without pure time discount and to rely instead completely on η. Allowing for $\delta < 1$, moreover, entails the risk of obtaining non–sustainable paths: For any combination of $\delta < 1$ and any $\eta \in]0, \infty[$ it is possible to find a transformation curve such that the consumption path that maximizes $W_{\eta,\delta}(c_1, c_2)$ is decreasing. Hence, from the perspective of sustainability there is support for the approach to intergenerational evaluation taken in the Stern Review, i.e. for abstaining from pure time discount.

In the following, we therefore assume $\delta = 1$ and, as the next logical step, inquire what levels of η appear to be plausible. There is considerable confusion about the "correct" value of η that should be used in cost–benefit analysis. So, in his comment on the Stern Review, Weitzman (2007*a*) calls $\eta = 2$ his "own rough point–guesstimate of what most economists might think are decent parameter values" (p. 707) for the Ramsey equation, where the notion "guesstimate" reflects well the methodological uncertainty with respect to η. In the following section, we first give a review on the empirical and experimental studies that have been carried out to determine η. To justify its specific choice of $\eta = 1$ the Stern Review mainly refers to such studies, in particular to Pearce & Ulph (1999).

[10]This is in line with the famous definition of sustainability given by the Brundtland Report (1987), p. 43, which says that economic development is to be called sustainable if it "meets the needs of the present without comprising the ability of future generations to meet their own needs." See also Asheim et al. (2001) for a theoretical justification of sustainability in this sense.

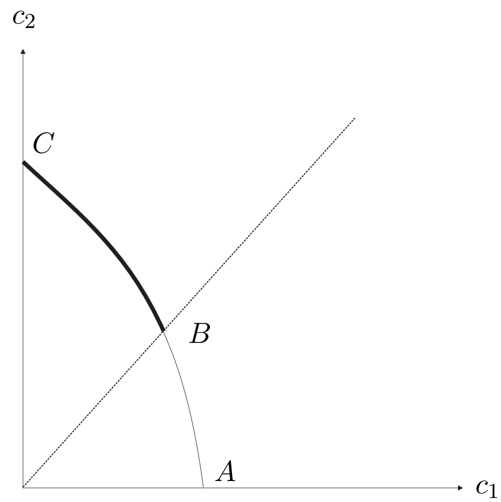

Figure 4: Sustainable consumption paths

3 Empirical studies on the size of η

There are various, conceptually rather different approaches to determine η through empirical observations. At the individual level, leaky bucket experiments and questionnaire studies, the idea of which can be traced back to Atkinson (1970), have been conducted in which test persons decide on hypothetical income distributions behind a veil of ignorance. Concerning the level of η the picture flowing from these studies is not uniform. Amiel et al. (1999) obtain fairly low values of η, essentially between 0 and 0.5 whereas the median of the parameter η found by Johansson-Stenman et al. (2002) lies between 2 and 3.[11]

A caveat of measuring the concavity of agents' utility functions is that in most of these experiments actually two concepts are mixed up, since concavity captures both risk aversion and inequality aversion. Carlsson et al. (2005) use an extension of the leaky bucket experiment in order to estimate individual risk aversion and inequality aversion separately. They find, that both are positively correlated, i.e. that people who are risk averse are also inequality averse, and that the median value of the parameter η seems to lie in an interval between 1 and 2. Studies on individual behavior on insurance markets, however, suggest values for η lying in the range between 1 and 4 (see Gollier (2006)).

In a recent study that partially also relies on the leaky bucket approach, Pirttilae & Uusitalo (2007) use representative surveys, in which questions on actual real–world economic situations were asked. In a first step, the inequality parameter η was found to be below 0.5, i.e. in the same order of magnitude as in the experimental results by Amiel et al. (1999). In a second step, questions were asked concerning the desirability of specific wage distributions. Here, the estimated η–values were considerably higher, i.e. greater than 3. The study of Pirttilae & Uusitalo (2007) thus shows, that the η–estimations are highly sensitive to the type of question asked and to the environment in which the survey or experiment is conducted.

[11] Meyer & Meyer (2005) stress that the level of η interpreted as the parameter of relative risk aversion crucially depends on the argument of the underlying von Neumann–Morgenstern utility function: If utility is related to consumption, η turns out to be much higher than in the case where wealth is the argument of the utility function.

Another type of research instead draws on observed market data to specify η. Some studies use micro data of peoples' lifetime consumption, and others exploit information on the agents' demand for preference–independent goods, such as food, in order to gain insight into their individual η-values. All studies, carefully reviewed in Evans (2006), also find values of η in the range between 1 and 2, which is similar to the estimations from the leaky bucket experiments and questionnaire approaches.

By a completely different method that refers to political instead of individual choices, it is explored what value for η governments implicitly use in their choices. In most of these studies, the η–values are derived by evaluating income tax schedules, as their degree of progression should reflect the inequality aversion of the government. Assuming that the tax schedule is based on the the principle of equal absolute sacrifice and that agents have CES–utility functions over income, the inequality aversion parameter η underlying the tax scheme can be estimated by using the equation

$$- ln(1 - T'(y)) = \eta \cdot ln\left(\frac{y}{y - T(y)}\right) \tag{9}$$

where y denotes income and $T(y)$ is the income tax schedule (see Cowell & Gardiner (1999) for an explanation of (9)). Using such an approach, Stern (1977) himself has, in a pioneering study, estimated an η-value of about 2. For the UK, Cowell & Gardiner (1999) have obtained values in the range between 1.3 and 1.4. Other estimates for OECD countries (see Evans (2005) and EU member countries (see Evans & Sezer (2005)) lie in a similar interval, with lowest values around 1.2 and highest values around 1.6.

This "revealed social value" approach (see Cowell & Gardiner (1999), p. 24, for this denomination), however, is quite controversial, since the results obtained that way crucially depend on the supposed functional form for individual preferences and on the type of the underlying sacrifice principle. So, assuming equal *relative* instead of equal *absolute* sacrifice produces completely different results such that "scepticism" to the usefulness of these estimates seems to be warranted (Creedy (2006), p. 15). Independent of the method applied the various studies do not provide a unique value for η but at most delimit a rather wide range for η–levels. Moreover, most studies rely on the stark simplification that there is a unique value for η whereas in reality η regularly varies with income (see, e.g., Atkinson & Brandolini (2007), p. 14–16).

But there is also a much deeper problem with these empirical studies. One has to carefully distinguish between individuals' attitudes towards inequality, reflected by their own preferences on the one hand, and the degree of inequality aversion, reflected by social welfare functions, on the other. The former measure indicates how people actually behave and how they feel about inequality, hence refers to the world as it *is*. The latter is a value judgement, i.e. tell us to what extent a social planner allows distributional concerns to affect policy decisions. In that sense it reflects how the world *ought to be* according to specific normative criteria. The Stern Review (with reference to Arrow (1995)) underlines the distinction between a "descriptive" and a "prescriptive" approach (Stern (2006), p. 47). But the Review does not proceed in a completely consistent way, as it backs up the choice of η primarily with reference to empirical estimates. Within Stern's normative approach, in which the level of η is held to be a "value judgement" (Stern (2006), p. 46), it would instead have been more suitable to determine η–values from explicit ethical criteria which, although in a not quite systematic way, is done in some studies around the Stern Review. In the following section we want to add to this and discuss some other ethical thought experiments that may be used for selecting appropriate values of η.

4 Ethical thought experiments on the size of η

4.1 Motivation and framework

In order to evaluate social welfare functions the common procedure is to examine whether they have some normatively appealing properties. So one can ask how different welfare criteria behave in certain technological environments and how their implications conform to ethical intuition. In this spirit, we have already noted previously that a true positive time discount, i.e. $\delta < 1$, may lead to a non sustainable development, which seems ethically hard to accept. Concerning the size of η, ethical plausibility is mostly – just as in the experimental studies – inferred from static leaky bucket considerations (see also Stern (2008)) that look at tolerable losses in aggregate income when there are transfers from one individual to another. In his extensive discussion of the Stern Review, Dasgupta (2008) in contrast has considered an infinite horizon linear growth model in which he showed that Stern's preferred choice $\eta = 1$ would imply an implausibly high savings rate. In order to avoid such excessive savings, Dasgupta (2008) concludes that a higher level of η, in the range between 2 and 4, would seem to be more appropriate.

In our thought experiments we describe normative relevant implications of particular η–values. Unlike the existing contributions, however, we do not simply invoke mere "plausibility" but instead refer to some explicitly formulated properties of welfare maximizing allocations, that are common in ethical social choice theory. To make the argument simple, we again present it in a basic model with only two generations and a linear technology, but generalization to a greater number of generations as in Dasgupta (2008) is straightforward. In this setting the linear transformation curve is given by

$$G(c_1, c_2) = c_1 + \frac{c_2}{m} = y \tag{10}$$

where $m > 1$ is the constant marginal rate of transformation between consumption in period 1 and period 2 and y is the exogenously given income of generation 1. If there were population growth with rate $p - 1$ and M is the marginal rate of transformation between aggregate consumption in period 1 and period 2, $m = \frac{M}{p}$ is the marginal rate of transformation on a per capita base.

Assuming equal treatment of both generations, i.e. $\delta = 1$, maximization of the social welfare function $W_{\eta,1}(c_1, c_2)$ as given by (6) yields for any given $\eta > 0$

$$c_1(m) = \frac{m\,y}{m + m^{\frac{1}{\eta}}} \tag{11}$$

$$c_2(m) = \frac{m^{\frac{1+\eta}{\eta}}\,y}{m + m^{\frac{1}{\eta}}} \tag{12}$$

for the optimal consumption levels in the two periods.

4.2 Solidarity between generations when productivity changes

For any fixed income y we first consider the changes that an increase in the productivity parameter m, i.e. technical progress, has on *both* generations. Irrespective of which welfare function is applied, a rising m will always benefit at least one of the two generations. It is, however, an appealing ethical condition that both generations should have their share in the advantages increased productivity brings about. Thus, the underlying welfare function should fulfill the following condition:

Solidarity S: Each generation should become better off in the welfare maximum when the productivity parameter m increases.

The welfare functions $W_{\eta,1}(c_1, c_2)$ that entail such intergenerational "circumstance solidarity"[12] can be characterized as follows:

Proposition 2 Condition S is fulfilled if and only if $\eta > 1$.

Proof. From (11) and (12) we obtain

$$c_1'(m) = \frac{\partial c_1}{\partial m} = \frac{m^{\frac{1}{\eta}}\left(1 - \frac{1}{\eta}\right) y}{\left(m + m^{\frac{1}{\eta}}\right)^2} \tag{13}$$

$$c_2'(m) = \frac{\partial c_2}{\partial m} = \frac{m^{\frac{1}{\eta}}\left(m^{\frac{1}{\eta}} + \frac{m}{\eta}\right) y}{\left(m + m^{\frac{1}{\eta}}\right)^2} \tag{14}$$

On the one hand, $c_2'(m) > 0$ holds for all $\eta > 0$. On the other, $c_1'(m) > 0$ is given if and only if $\eta > 1$. ■

With $\eta < 1$ consumption of generation 1 even goes to zero in the linear case if productivity goes to infinity, which would mean an extremely uneven distribution of the benefits of technical progress. The excessive savings problem which lies at the heart of the problem of intertemporal evaluation would then be exacerbated with growing m, which clearly contradicts ethical intuition and makes the choice of $\eta < 1$ hard to accept. If $\eta = 1$, consumption of generation 1 remains constant at the level $\frac{y}{2}$ irrespective of any changes in m. If $\eta > 1$ generation 1's consumption $c_1(m)$ eventually approximates the income y with m going to infinity. The development of the consumption profile $(c_1(m), c_2(m))$ for the three cases $\eta < 1$, $\eta = 1$ and $\eta > 1$ is visualized in Figure 5.[13]

Concerning ethically satisfactory values of η, our considerations hence suggest $\eta = 1$ as a minimum level if one wants to avoid excessive savings and the expropriation of the earlier generation in the presence of technical progress. This also confirms Weitzman (2007*a*), p. 707, who states – without some further explanation – that $\eta = 1$ is "the lowest lower bound of just about any economist's best guess range."

4.3 No–envy between generations

Absence of envy is a commonly used benchmark for evaluating the equity of allocations (see, e.g., Foley (1967), Kolm (1972), Kolm (1998), and Varian (1974)). In our context, this means, that if generation 1 is put into the shoes of generation 2 and vice versa, no generation should want to change places and to get the consumption level of its counterpart. There are different ways to make the no–envy criterion operational. The simplest

[12]This notion has been coined by Fleurbaey (2008), p. 27: "The idea is that there should be some solidarity among individuals in order to share the bad or good luck of change in circumstances affecting some of them."

[13]For some generalization of Proposition 2 to the case of non–linear transformation curves and to the case of risky outcomes see Buchholz & Schumacher (2009).

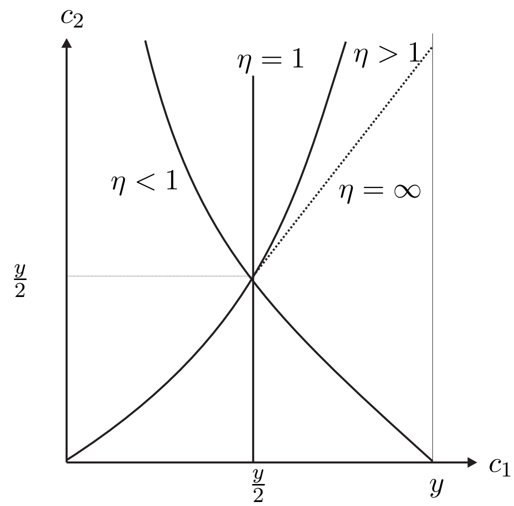

Figure 5: Consumption paths for different η–values.

way is to apply it to absolute consumption level which implies equality of consumption across generations:

Equality of Consumption EC: Both generations should have equal consumption in the welfare maximum.

With this condition EC we would obtain an extreme value of η.

Proposition 3 Condition EC is fulfilled if and only if $\eta = \infty$.

Proof. This result follows directly from (11) and (12) by letting η go to infinity. ■

It is not surprising that this outcome corresponds to the difference principle stated by Rawls (1971). If productivity m increases with $\eta = \infty$ the solution is chosen that maximizes the consumption of the least well–off generation, which, in a productive economy, is generation 1 (see also Figure 5).

In a productive economy with $m > 1$, applying the no–envy criterion to unadjusted levels of consumption, however, might seem to be questionable, since the economic situation of both generations is inherently different. Taking productivity into account gives the following alternative no–envy condition:

No–envy in the absolute sense NEA: Generation 1 (generation 2) does not envy generation 2 (generation 1) in an allocation $(\tilde{c}_1, \tilde{c}_2)$ if $\tilde{c}_1 \geq \frac{\tilde{c}_2}{m}$ $(\tilde{c}_2 \geq m\,\tilde{c}_1)$.

Consumption of $\tilde{c}_1$ in period 1, if postponed, would transform into consumption of $m\tilde{c}_1$ in period 2. Analogously, consumption of $\tilde{c}_2$ in period 2 corresponds to lower consumption $\frac{\tilde{c}_2}{m}$ in period 1. Condition NEA clearly implies $\tilde{c}_2 = m \cdot \tilde{c}_1$. This property can also be justified by the following normative requirement, which means that the initial endowment is to be shared equally among generations:

Equal resource claims ER: In an allocation $(\tilde{c}_1, \tilde{c}_2)$ both generations should benefit from the same share of the initial endowment.

These normative conditions give a justification for $\eta = 1$ in the following sense:

Proposition 4 A feasible allocation $(\tilde{c}_1, \tilde{c}_2)$ fulfills NEA or, equivalently, ER if and only if it maximizes $W_{1,1}(c_1, c_2)$ under the feasibility constraint (10).

Proof. It is seen by a short calculation that combining $\tilde{c}_2 = m\tilde{c}_1$, i.e. NEA, with the feasibility constraint (10) gives the same allocation as (11) and (12) if and only if $\eta = 1$. ■

As an alternative to NEA one could assume that agents do not compare their absolute productivity adjusted consumption levels as in NEA but instead their relative positions, i.e. their "status".[14] This yields the following condition:

No–envy in the relative sense NER: Generation 1 (generation 2) does *not envy* the status of generation 2 (generation 1) in the allocation $(\tilde{c}_1, \tilde{c}_2)$, if $\frac{\tilde{c}_1}{\tilde{c}_2} \geq \frac{\tilde{c}_2/m}{\tilde{c}_1}$ $(\frac{\tilde{c}_2}{\tilde{c}_1} \geq \frac{m\tilde{c}_1}{\tilde{c}_2})$.

These conditions lead to the parameter value $\eta = 2$:

Proposition 5 A feasible allocation $(\tilde{c}_1, \tilde{c}_2)$ fulfills NER if and only if it maximizes $W_{2,1}(c_1, c_2)$ under the feasibility constraint (10).

Proof. NER is equivalent to $\tilde{c}_2^2 = m\tilde{c}_1^2$. Combining this with (10) gives the same allocation as (11) and (12) if and only if $\eta = 2$. ■

Propositions 4 and 5 show that allocations which fulfill some equity–concerned no–envy requirements can be selected by specific utilitarian welfare functions as well. This provides some justification for the use of the specific parameter values $\eta = 1$ or $\eta = 2$. It is quite reassuring that the values for η obtained in this way lie in a range that is not in contrast to the results of the empirical studies on η.

5 The critique of the Stern Review's approach to intergenerational valuation – a comment

The main message of the Stern Review, i.e. that strong immediate action to combat climate change is necessary to protect mankind from serious harm, heavily rests upon the Review's specific approach to take future environmental damages into account. So it is no surprise that many of the objections that have been put forward against the Stern Review and its conclusions are centered around basic issues of evaluation over time. Even though most critics consider the value of η chosen by Stern as too low, the severity of the objections differs very much.

A rather modest objection is only concerned with the specific choice of the inequality aversion parameter η, while, in principle, it accepts the ethically based social welfare function approach and the choice of a near–zero value for the pure time preference parameter ρ. So Dasgupta (2006, 2008) admits that that he personally "does not know how to justify $\rho > 0$ in a deterministic world", so that "we should instead experiment with η" (p. 16).

[14] Status concerns are held to influence agents' economic decisions in a wide range of domains. See, e.g., Veblen (1899), Ireland (1998), Bolton & Ockenfels (2000), Falk & Knell (2004), Luttmer (2005).

But in contrast to Stern, Dasgupta (2008) prefers a higher value for η which is more in favor of the present generation (see already Section 4 of this paper).

Another attack of prominent economists against the Stern Report (see above all Nordhaus (2007) and Weitzman (2007*a*)) goes much deeper, as it does not accept the ethically motivated use of social welfare functions as such. According to this view, policy recommendations must in general not be based on the subjective preferences of virtual philosophers but on the actual preferences of real people. These individual preferences, so it is held, are revealed by the interest rate on the capital market, which therefore should guide political actions also in the field of climate change.

On closer inspection, however, it seems doubtful whether the market interest rate in fact can be an adequate expression of the agents' intertemporal preferences just when future generations are involved.[15] There are market imperfections as, e.g., a divergence between agents' economic and political preferences (Nyborg (2000)), unduly high personal risk premia, imperfect property rights (Sinn (2008)) or Sen's famous "assurance problem" (Sen (1967)), that may prevent intergenerational altruism of present people from materializing through isolated transactions in the market place.[16]

Apart from these substantial difficulties to derive long–term social discount rates from observed market data, a more fundamental problem arises since some of Stern's critics even seem to deny the ethical dimension of climate change policy. From the conceptual viewpoint such an anti–ethical position which shows up in derogating remarks on Stern's normative welfare–theoretic approach (see, e.g., Nordhaus (2007), p. 691), however, is quite misleading: As soon as actions of some people ("the current generation") affect other defenseless people ("the future generation") that, because of the asymmetry of time, cannot take part in the decision process today, either one opts for complete laissez–faire ("let them alone") or one has to look for some standards or norms that should guide responsible behavior towards them. This implies that not yet born people need to receive consideration in their own right (see Padilla (2002)). Here, ethics unavoidably comes into play because its classical task is to reflect rules for morally acceptable behavior towards others that are dependent on us. In face of the long–run consequences of climate change policy we therefore "cannot help being ethical from the start" (Broome (2006), p. 81) and "that we can't select either discount rate without making ethical judgements" (Heal (2008), p. 7). Also ordinary people perceive the problem of climate change as an ethical one. Otherwise, the public debate on it would not be so heated.

But this leads to question how much economics should become involved in the ethical debate. One can hold the position that economics should specialize on empirically oriented research while ethical thinking should remain limited to moral philosophy. Then the question is not whether there should be ethical reflection at all but rather who is in charge of it. Concerning such a division of labor in science no clear–cut and everlasting rules exist. But there are some good reasons to keep part of ethics within the economic discipline:

(i) The impacts of climate change policy are usually evaluated by means of intertemporal social welfare functions that are a standard tool of economic analysis and whose parameters unavoidably reflect ethical value judgements. Furthermore, there are "few moral philosophers with the command of the technical apparatus of economics

[15] For a critical assessment of Nordhaus' (2007) and Weitzman's (2007) argument see also Heal (2008), pp. 8-9.

[16] This is to mean that benevolent behavior towards future generations only pays for an altruistic individual if she can be sure that a sufficient number of other individuals will act in the same way. For a discussion see Hepburn (2006*b*).

required" (Hausman & McPherson (1996), p. 207). Why then leave this important field to non–experts? In many fields, welfare economics seems to be a good instrument for improving the intellectual quality of ethical judgement.

(ii) Even though moral thinking is subjective it is by no means irrational if the aim is to make ethical decisions in a systematic and coherent way. Rational choice theory, however, is a centerpiece of economics. There is a long tradition in economics (see already Koopmans (1960)) to explore which intertemporal social welfare functions fulfill specific normative conditions, as we have, focussing on the value of η, done here in this paper.

(iii) One could argue that caring for the well–being of future people may, in the long run, make groups more stable and improve the propagation of the group members' genes. Intergenerational altruism, not necessarily restricted to one's own descendants, may thus be favored by natural selection in the process of evolution which, to some degree, makes it incorporated in individual genes.[17] The problem is that such motivations guided by 'natural instinct' do not translate directly into purposeful human action. Additionally, rationality as a human behavioral pattern is required to put such general attitudes to work. In many situations, however, it is by far not obvious what rationality is to mean. Rather, a thorough theoretical analysis is – also in the context of altruistic preferences – needed to infer criteria for rational behavior, which is the economists daily bread. In this perspective, no contradiction exists between having real people whose fundamental aspirations are genetically codified, on the one hand, and conducting rational ethical choice theory, on the other.

Even if one acknowledges that economics should contribute to the ethical debate on climate change some caveats are warranted:

(i) Normative judgement in general and social welfare functions clearly cannot be determined in an objective way. What some people think to be ethically desirable, is in the end a matter of personal taste that should not be forced upon others. Nevertheless, in the context of intertemporal analysis, one has to start from some criteria that necessarily have a subjective element, at least for pragmatic reasons. On the one hand, this might raise the danger of misuse of scientific judgement, but on the other hand, the results of such analysis are an important input to the public discourse. The purpose of welfare economics is not to make definite prescriptions but rather to provide a framework that helps to make the ethical argument and the underlying normative values more transparent.

(ii) It is a plain truth that "[w]hat is appropriate for a democratic government is a different question from what is normatively justifiable " (Atkinson (2001), p. 199). Nevertheless, in a liberal democracy moral reasoning of philosophers or welfare economists can never replace the consent of a majority. So the question arises how abstract criteria for intergenerational evaluation match the moral and other–regarding preferences of real–world voters. Even though people discount future benefits they often attach higher value to the utility of their descendants and may even be willing to sacrifice their life for them (see Binmore (2007), p. 13). In the intertemporal context other

[17] See Stern (2008), p. 15, for some hint at the evolutionary perspective. For a theory on the determination of discount rates in the evolutionary process see Rogers (1994).

behavioral "anomalies" with some normative significance have been identified by experimental studies. So, people regularly prefer patterns of utility increasing over time to decreasing ones which might, from the viewpoint of behavioral economics, provide some support for sustainability as a specific objective of intertemporal choice.[18] Beyond pure introspection, there is, however, not so much research on the interrelation between ethical and behavioral approaches until now.[19] In this context a modest contribution of our paper could be that concerning the level of η there are no sharp discrepancies between observed behavior and the outcome of normative deductions.

(iii) Even if one accepts the ethical perspective and the concomitant use of welfare functions one might nevertheless find Stern's welfare theoretic framework too simplistic. So the utility function by which consumption of each generation is evaluated is equally considered as the von Neumann–Morgenstern utility function in the case of risk. This, however, is not without problems since it may produce ethically ambiguous results.[20] While, as described in this paper, a lower η benefits the future generation because of less consumption smoothing over time, it simultaneously decreases precautionary savings since prudence of the underlying utility function is decreased.[21] In order to overcome these difficulties one can try to disentangle the attitudes towards consumption smoothing over time and towards risk (see Kreps & Porteus (1978) and the discussion in Gollier (2001), pp. 297-304). Specifically, this would mean that there are two η–values, one expressing the degree of relative resistance to intertemporal substitution (as in this paper) and the other capturing the relative degree of risk aversion (see Epstein & Zin (1991)). Other dimensions of risk and uncertainty, i.e. the danger of catastrophic losses, are treated in Weitzman (2007a, 2007b) and Gollier (2008).

(iv) At a much more fundamental level, there are also doubts as to whether the classical welfare theoretic approach as such is really capable of grasping the essential issues of policymaking for future generations. So Summers & Zeckhauser (2008) "do not believe that an argument about these alternative parameter values [η, ρ and g appearing in the Ramsey rule, W.B. and J.S.] will resolve our policy making concerns" (p. 118). Rather they reflect upon some topics such as population growth, amenity values increasing in the course of economic development, and motivational aspects like intergenerational altruism and loss aversion, that are relevant for judging policy measures with very long–run consequences. Moreover, taking externalities into account, will change relative prices and thus the social discount rate (see Hoel & Sterner (2007). From this perspective, Stern's approach may appear too schematic and textbook–like. Specific criteria for intertemporal evaluation, however, do not result from Summers & Zeckhauser's deliberate but informal discussion.

For the further discussion of the ethics of climate change the issues listed above (ethical

[18] See, e.g., Frank (1993) and, as a critical assessment of experimental studies leading to similar results, Frederick & Loewenstein (2008).

[19] Even though Frederick et al. (2002) and Zeckhauser & Viscusi (2008) consider both behavioral and ethical approaches, they do not make explicit what they may contribute to each other. The possible tensions between stated and revealed ethics is discussed in Dietz et al. (2008).

[20] On the consequences arising from the use of EU–Theory for intergenerational evaluation see Buchholz & Schumacher (2008).

[21] See, e.g., Gollier (2001) for the conceptual foundations of this argument. This ambiguity has been observed by Dasgupta (2008) and is further explored in Bauer & Buchholz (2008).

attitudes of real people and political acceptability of ethical standards, the dimensions of risk and uncertainty in intertemporal evaluation, the range of the classical welfare theoretical approach) will be of particular importance.

6 Conclusion

The Stern Review has not only stimulated the discussion on social discounting, but has reinforced some shift of emphasis. Instead of focusing on the pure time preference rate ρ as in the standard literature on evaluation over time, the Report (as other more recent contributions) mainly uses the inequality aversion parameter η (that characterizes the transformation function underlying the intertemporal social welfare function) to bring about a balance of interest between different generations. In this way, an ethically questionable unequal treatment of generations is avoided and, additionally, the danger of a non–sustainable development, i.e. decreasing consumption along an optimal path, is excluded, which has been shown in this paper. This supports the view, that it seems preferable to look primarily at η (and not at ρ) when intergenerational distribution is at stake. Having this change of paradigm in the economist's perception of intertemporal evaluation, the next question naturally is to find the appropriate level for the parameter η. The Stern Report itself remains very short on that, partly referring to a few empirical studies on the size of η. In total, however, empirical and experimental evidence is not uniform, since it presents a broad range of η values, going from near zero to values larger than 3. It is, however, doubtful, whether such observed data can serve as a sound basis for decisions, when normative criteria for the ethically appropriate treatment of other persons, i.e. future generations, are to be found. As it is common in social choice theory, we therefore considered some simple normative properties in order to delimit the range of η. Through these thought experiments it has in particular become clear that $\eta = 1$, as in the main part of the Stern Report, is a lower bound for reasonable values of inequality aversion when excessive savings in the face of productivity changes is to be avoided and the condition of "circumstance solidarity" is to be respected. Moreover, it could be shown that the specific values $\eta = 1$ and $\eta = 2$ fulfill two different no–envy conditions.

As compared to these considerations within the theoretic framework adopted by Stern, a much more fundamental problem is that some of the Review's critics completely deny its underlying ethical intention and stick instead to a pragmatic and somehow ad hoc approach. Hence, a systematic discussion on the relationship between ethics and economics in the field of climate change nevertheless seems to be highly desirable. On the one hand, at the methodological level, it can be seen as a major merit of the Stern Review that it has provided a kick–off for such a debate. On the other hand, as has also been discussed in our paper, the solution proposed by Stern will not be the last word in the discounting debate, since a broader perspective on issues of intergenerational fairness might turn out to be more suitable. Such a debate, however, is just starting.

7 References

Amiel, Y., J. Creedy & S. Hurn (1999), 'Measuring attitudes towards inequality', *Scandinavian Journal of Economics* **101**, 83–96.

Arrow, K. J. (1995), Intergenerational equity and the rate of discount in long–term social investment. Paper at the IEA World Congress, www-econ.stanford.edu/faculty/workp/swp97005.htm.

Arrow, K. J. (1999), Discounting, morality and gaming, *in* P. R.Portney & J. R.Weyant, eds, 'Discounting and Intertemporal Equity', Resources for the Future, Washington, DC.

Asheim, G. & W. Buchholz (2003), 'The malleability of undiscounted utilitarianism as a criterion of intergenerational justice', *Economica* **70**, 405–422.

Asheim, G., W. Buchholz & B. Tungodden (2001), 'Justifying sustainability', *Journal of Environmental Economics and Management* **41**, 252–268.

Atkinson, A. B. (1970), 'On the measurement of inequality', *Journal of Economic Theory* **2**, 244–263.

Atkinson, A. B. (2001), 'The strange disappearence of welfare economics', *Kyklos* **54**, 193–206.

Atkinson, A. B. & A. Brandolini (2007), On analysing the world distribution of income. Discussion Paper, University of Oxford.

Bauer, C. & W. Buchholz (2008), How changing prudence and risk aversion affect optimal saving. CESifo Working Paper No. 2438.

Binmore, K. (2007), Interpersonal comparison of utility. Discussion Paper, University College London.

Böhm-Bawerk, E. v. (1891), *The Positive Theory of Capital (Engl. Translation of: Die positive Theorie des Kapitals)*, Glasgow.

Bolton, G. E. & A. Ockenfels (2000), 'A theory of equity, reciprocity, and competition', *American Economic Review* **90**, 166–193.

Broome, J. (1994), 'Discounting the future', *Philosophy and Public Affairs* **23**, 128–156.

Broome, J. (2004), *Weighing lives*, Oxford University Press, Oxford.

Broome, J. (2006), Valuing policies in the response to climate change: Some ethical issues. A contribution to the work of the Stern Review on the economics of climate change. Discussion Paper, University of Oxford.

Brundtland Report (1987), *Our common future*, Oxford University Press, Oxford (UK).

Buchholz, W. (2003), Balancing the interests of the present and the future, *in* C.Böhringer & A.Löschel, eds, 'Empirical modeling of the economy and the environment', ZEW Economic Studies, vol. 20, Heidelberg et al., pp. 315–326.

Buchholz, W. & J. Schumacher (2008), EU–Theory and intergenerational ethics: match or mismatch? Presentation at the Workshop 'Conceptualizing Sustainability under Uncertainty' at Camp Reinsehlen on October 3, 2008.

Buchholz, W. & J. Schumacher (2009), Increasing productivity and intergenerational distribution: Some extensions. mimeo.

Carlsson, F., D. Daruvala & O. Johansson-Stenmann (2005), 'Are people inequality averse or just risk averse?', *Economica* **72**, 375–396.

Cowell, F. A. & K. Gardiner (1999), Welfare weights. STICERD, London School of Economics, OFT Economic Research Paper No. 202.

Creedy, J. (2006), Evaluating policy: Welfare weights and value judgements. University of Melbourne, Department of Economics, Research Paper No. 971.

Dasgupta, P. (2001), *Human Well–Being and the Natural Environment*, Oxford University Press, Oxford.

Dasgupta, P. (2008), 'Discounting climate change', *Journal of Risk and Uncertainty* **37**, 141–169.

Dasgupta, P. & G. M. Heal (1979), *Economic theory and exhaustible resources*, Cambridge University Press, Cambridge (UK).

Dietz, S., C. Hepburn & N. Stern (2008), Economics, ethics and climate change. Discussion Paper, http://ssrn.com/abstract=1090572.

Epstein, L. G. & S. Zin (1991), 'Substitution, risk aversion and the temporal behavior of consumption and asset returns: An empirical famework', *Journal of Political Economy* **99**, 263–286.

Evans, D. J. (2005), 'The elasticity of marginal utility of consumption: Estimates for 20 OECD countries', *Fiscal Studies* **26**, 197–224.

Evans, D. J. (2006), Social discount rates for the European Union. Milan European Economy Workshops, Working–Paper 2006-20.

Evans, D. J. & H. Sezer (2005), 'Social discount rates for member countries of the European Union', *Journal of Economic Studies* **32**, 47–59.

Falk, A. & M. Knell (2004), 'Choosing the Joneses: Endogenous goals and reference standards', *Scandinavian Journal of Economics* **106**, 417–435.

Fleurbaey, M. (2008), *Fairness, Reciprocity, and Welfare*, Oxford University Press, Oxford.

Foley, D. (1967), 'Resource allocation and the public sector', *Yale Economic Essays* **7**, 45–98.

Frank, R. (1993), 'Wages, seniority, and the demand for risky consumption profiles', *Journal of Economic Behavior and Organization* **21**, 251–276.

Frederick, S. & G. Loewenstein (2008), 'Conflicting motives in evaluations of sequences', *Journal of Risk and Uncertainty* **37**, 221–235.

Frederick, S., G. Loewenstein & T. O'Donoghue (2002), 'Time discounting and time preference: A critical review', *Journal of Economic Literature* **40**, 351–401.

Gollier, C. (2001), *The economics of risk and time*, The MIT Press, Cambridge (MA) and London.

Gollier, C. (2006), An evaluation of the Stern Report on the economics of climate change. IDEI working papers no. 464. http://idei.fr/doc/wp/2006/stern.pdf.

Gollier, C. (2008), 'Discounting with fat-tailed economic growth', *Journal of Risk and Uncertainty* **37**, 171–186.

Harrod, R. F. (1948), *Towards a dynamic economy*, McMillan, London.

Hausman, D. M. & M. McPherson (1996), *Economic Analysis and Moral Philosophy*, Cambridge University Press, Cambridge.

Heal, G. (2008), Climate change economics: A meta–review and some suggestions. NBER Working Paper No. 13927.

Hepburn, C. (2006*a*), Discounting climate change damages: Working note for the Stern Review. Discussion Paper, University of Oxford.

Hepburn, C. (2006*b*), Valuing the far–off future: Discounting and its alternatives. Discussion Paper, University of Oxford.

Hoel, M. & T. Sterner (2007), 'Discounting and relative prices', *Climatic Change* **84**, 265–280.

Ireland, Norman J. (1998), 'Status–seeking, income taxation and efficiency', *Journal of Public Economics* **70**, 99–113.

Johansson-Stenman, O., F. Carlsson & D. Daruvala (2002), 'Measuring future grandparents' preferences for equality and relative standing', *Economic Journal* **112**, 362–383.

Kolm, S.-Ch. (1972), *Justice et Equité*, Editions du CNRS, Paris.

Kolm, S.-Ch. (1998), *Modern theories of justice*, 7th edn, The MIT Press, Cambridge (MA) and London.

Koopmans, T. C. (1960), 'Stationary ordinal utility and impatience', *Econometrica* **28**, 287–309.

Kreps, D. M. & E. L. Porteus (1978), 'Temporal resolution of uncertainty and dynamic choice theory', *Econometrica* **46**, 185–200.

Luttmer, E. F. P. (2005), 'Neighbors as negatives: Relative earnings and well-being', *The Quarterly Journal of Economics* **120**(3), 963–1002.

Marini, G. & P. Scaramozzino (2000), 'Social time preference', *Journal of Population Economics* **13**, 639–645.

Mas-Colell, Andreu, Michael D. Whinston & Jerry R. Green (1995), *Microeconomic Theory*, Oxford University Press, New York.

Meyer, D. J. & J. Meyer (2005), 'Relative risk aversion: What do we know?', *Journal of Risk and Uncertainty* **31**, 243–262.

Nordhaus, W. (2007), 'A review of the Stern Review on the Economics of Climate Change', *Journal of Economic Literature* **45**, 686–702.

Nyborg, K. (2000), 'Homo economicus and homo politicus: Interpretation and aggregation of environmental values', *Journal of Economic Behavior and Organization* **42**, 305–322.

Olson, M. & M. J. Bailey (1981), 'Positive time preference', *Journal of Political Economy* **89**, 1–25.

Padilla, E. (2002), 'Intergenerational equity and sustainability', *Ecological Economics* **41**, 69–83.

Pearce, D. W. & D. Ulph (1999), A social discount rate for the UK, *in* D. W.Pearce, ed., 'Economics and the Environment: Essays in Ecological Economics and Sustainable Development', Edward Elgar, Cheltenham.

Pigou, A. C. (1932), *The economics of welfare*, McMillan, London.

Pirttilae, J. & R. Uusitalo (2007), Leaky bucket in the real world: Estimating inequality aversion using survey data. CESifo Working Paper No. 2026.

Ramsey, F. P. (1928), 'A mathematical theory of saving', *Economic Journal* **38**, 543–559.

Rawls, J. (1971), *A Theory of Social Justice*, Oxford University Press, Oxford.

Rogers, A. R. (1994), 'Evolution of time preference by natural selection', *American Economic Review* **84**, 460–481.

Romer, D. (2006), *Advanced Macroeconomics*, 3rd edn, McGraw–Hill/Irwin, New York.

Sen, A. (1967), 'Isolation, assurance and the social rate of discount', *Quarterly Journal of Economics* **81**, 112–124.

Sinn, H.-W. (1987), *Capital Income Taxation and Resource Allocation*, North Holland, Amsterdam et al.

Sinn, H.-W. (2008), 'Public policies against global warming: A supply side approach', *International Tax and Public Finance* **15**, 360–394.

Stern, N. (1977), Welfare weights and the elasticity of the marginal valuation of income, *in* M.Artis & A. R.Nobay, eds, 'Studies in Modern Economic Analysis', Basil Blackwell, Oxford.

Stern, N. (2006), The economics of climate change: The Stern Review. http://www.hm-treasury.gov.uk.

Stern, N. (2008), 'The economics of climate change', *American Economic Review, Papers and Proceedings* **98**, 1–37.

Summers, L. H. & R. J. Zeckhauser (2008), 'Policymaking for posterity', *Journal of Risk and Uncertainty* **37**, 115–140.

The Economist (2006), Shots across the Stern – Was Sir Nicholas' big report on climate change egalitarian, inegalitarian – or both? Economic Focus, December 13, 2006.

Varian, H. (1974), 'Equity, envy and efficiency', *Journal of Economic Theory* **29**, 217–244.

Varian, H. (2006), 'Recalculating the costs of global climate change', *The New York Times* . December 14, 2006.

Veblen, T. (1899), *The Theory of the Leisure Class*, MacMillan, New York.

Weitzman, M. L. (2007*a*), 'A review of the Stern Review on the economics of climate change', *Journal of Economic Literature* **45**, 703–724.

Weitzman, M. L. (2007*b*), On modeling and interpreting the economics of catastrophic climate change. Discussion Paper, www.economics.harvard.edu/faculty/weitzman/files/modeling.pdf .

Zeckhauser, R. & W. Viscusi (2008), 'Discounting dilemmas: Editors' introduction', *Journal of Risk and Uncertainty* **37**, 95–106.