DISCOUNTING AND WELFARE ANALYSIS OVER TIME: CHOOSING THE η

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Abstract

Based on the Ramsey equation and an ethically motivated 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. We support this position by showing that, also from the view point of sustainability, application of η is preferable to the use of the pure time discount parameter ρ when a balanced distribution of utility across generations is to be brought about. After reviewing empirical studies on the size of η we develop a novel axiomatic approach based on non–envy criteria by which we obtain values for η lying in a range between 1 and 2. Whereas the starting point of the Stern Review quite explicitly is an ethical one, many critics of the Review deny this ethical stance and thus – as described in our paper – miss a crucial element of the Stern Review.

JEL Code: D6, D9, Q5.

Keywords: Ramsey equation, discounting, sustainability, non-envy.

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1 Introduction

The evaluation of consumption– and utility–streams over time by means of discounted utilitarian objective functions has been a main topic of economic research for a long time. The most important questions that economists have sought and still search to answer 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 when determining the social discount rate? Is discounting of costs and benefits justified at all when future generations are involved, since it may be considered as unfair to them? The recent publication of the Stern Review on the economics of climate change (Stern (2006)) has further stimulated this ongoing debate on discounting which even got some broader publicity that way (The Economist (2006), Varian (2006)).

In the Stern Report, as in many other recent contributions, the discount rate r is determined through the *Ramsey equation* that originally stems from the theory of economic growth (Ramsey (1928)). As a necessary (and very 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 of the marginal rate utility of consumption (for a given isoelastic utility function) and the consumption growth rate $g(t) = \frac{\dot{c}(t)}{c(t)}$. Omitting the time variable t, the Ramsey rule precisely states that along an optimal growth path

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

has to hold for all points of time within the planning horizon.

Putting equation (1) into the focus of the treatment of discounting is very helpful to clarify two issues that often have remained rather obscure in the discussion of intertemporal evaluation. So, 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 welfare in the present and in the future, 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's (1891) first reason for a positive interest rate 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 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.[1] From this viewpoint, avoiding pure time discount and relying instead on the parameter η when deciding on intergenerational distribution is preferable, because in this way systematic discrimination against people that

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

are "unlucky" to appear later on the time axis will not occur. The Stern Review essentially shares this ethically based point of view by applying a positive ρ only to capture the small risk that the human species might be extinct (by a meteorite or so).[2] Concerning the normative foundation of intertemporal evaluation, the Report and its critics consequently concentrate on the choice of η which, with this rigour, has not been quite common in intertemporal welfare economics until recently. In this paper, we follow this approach, reflecting further the use of η as a determinant of intertemporal allocation.

In our analysis, we will proceed as follows: In order to make the basic relationships as transparent as possible, in Section 2 we explain the interchangeability of ρ and η in a simple two–period–model. In particular, it can be shown in this way, that invoking "sustainability" as a commonly shared condition for intertemporal allocations 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, generally, normative context. In Section 4 we develop an axiomatic approach for specifying parametrical values of η, thus employing the standard method in ethical social choice theory. In Section 5 we discuss some of the critical comments raised against the Stern Review and its preferences of η over ρ. Section 6 concludes.

2 Intertemporal choice in a two–period–setting

2.1 An argument in favor of pure time discount

Assume that in a world of full certainty[3], 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. 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 *transformation 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 solves the following optimization problem:

$$W(c_1, c_2) \;\rightarrow\; \max_{c_1, c_2} \text{ s.t. } G(c_1, c_2) = g \tag{3}$$

Omitting variables, the first order condition for an interior solution of this maximization problem is given by

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

[2] For a review of the philosophical (non–)legitimization of pure time discount see, e.g., Broome (1994) and Broome (2004).

[3] Concentrating on the basic ethical issues of intertemporal choice in this paper we do not discuss all the important problems that are related to risk and uncertainty. In particular, we will not deal with the different interpretation of η as a parameter of relative risk aversion as done in the Stern Review.

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

Here

$$\pi(u_1, u_2) := \frac{h'(u_1)}{h'(u_2)} \tag{5}$$

$$\mu(c_1, c_2) := \frac{u'(c_1)}{u'(c_2)} \tag{6}$$

are the relevant *marginal rates of substitution* given $h(u)$ and $u(c)$, and

$$\gamma := \frac{\partial G/\partial c_1}{\partial G/\partial c_2}(c_1, c_2) \tag{7}$$

is the *marginal rate of transformation* between consumption of generation 1 and generation 2 at some (c_1, c_2).

With the help of condition (4) a standard argument in favor of pure time discounting, i.e. $\rho > 0$ and thus $\delta < 1$, can now be easily explained 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 (4) cannot be fulfilled as in this case for all points along the transformation curve we have

$$\pi \cdot \mu = 1 \cdot 1 < 1 \cdot \gamma = \delta \cdot \gamma \tag{8}$$

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 maximal when the whole consumption is postponed to period 2 and generation 1 is forced into a state of poverty.[6]

The earlier generation 1 can be protected against such an excessive sacrifice 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

[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.

[6]In an infinite generation setting the "jam tomorrow" paradox would arise, 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) on that.

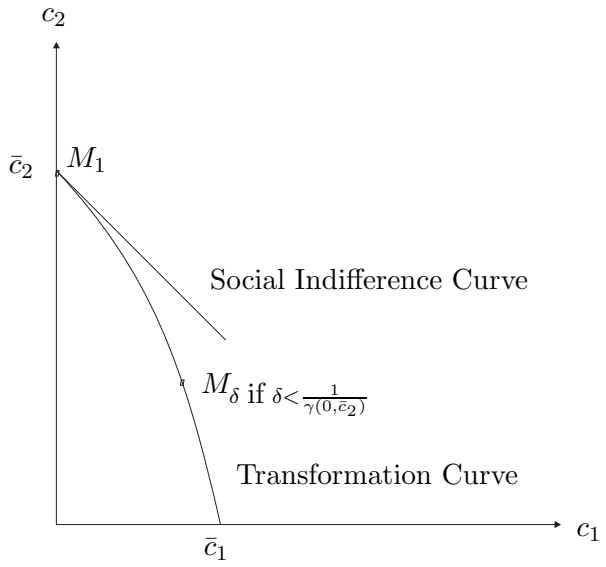

Figure 1: Expropriation of the earlier generation in a productive economy without utility discounting and inequality aversion.

of consumption in this way is a classical justification for discounting in the intertemporal social welfare function.[7]

2.2 The interchangeability between ρ and η

The same safeguard for the earlier generation, however, can be provided by having 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 social evaluation we concentrate our attention on the second possibility. 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

$$h(c_t) = \begin{cases} \frac{c_t^{1-\eta}}{1-\eta} & \text{for } \eta > 0,\ \eta \neq 1 \\ ln\, c_t & \text{for } \eta = 1 \end{cases} \tag{9}$$

where η, as the elasticity of the central planner's marginal valuation of individual utility/consumption, indicates the planner's degree of inequality aversion (as in Atkinson's (1970) classical approach to inequality measurement). Having again $\delta = \frac{1}{1+\rho}$, the social welfare function is

$$W_{\eta,\delta}(c_1, c_2) = \frac{c_1^{1-\eta}}{1-\eta} + \delta \frac{c_2^{1-\eta}}{1-\eta} \tag{10}$$

The marginal condition (4) is fulfilled for some consumption profile $(\tilde{c}_1, \tilde{c}_2)$ if

$$\left(\frac{\tilde{c}_2}{\tilde{c}_1}\right)^{\eta} = \delta\gamma\left(\tilde{c}_1, \tilde{c}_2\right) \tag{11}$$

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

which gives a simple analogue of the Ramsey equation in the two–period–model.[8]

Based on (11) we now want to work out explicitly how a certain allocation $(\tilde{c}_1, \tilde{c}_2)$ may be implemented by different combinations of δ and η. This consideration, in particular, shows how a given pure time preference δ may be replaced by an appropriately chosen inequality aversion η without giving rise to a different welfare maximum. To describe this substitutability between δ and η more closely, we take the logarithm of (11) and solve the equation thus obtained for η. For a given $(\tilde{c}_1, \tilde{c}_2)$ on the transformation curve and letting $\delta^*(\tilde{c}_1, \tilde{c}_2) := \frac{1}{\gamma(\tilde{c}_1, \tilde{c}_2)}$ this yields

$$\eta(\delta) = \frac{ln\,\delta - ln\,\delta^*(\tilde{c}_1, \tilde{c}_2)}{ln\,\tilde{c}_2 - ln\,\tilde{c}_1} \tag{12}$$

To interpret (12), we distinguish three cases.

Case 1: $\tilde{c}_2 > \tilde{c}_1$, i.e. $ln\left(\frac{\tilde{c}_2}{\tilde{c}_1}\right) > 0$
$\delta \geq \delta^*(\tilde{c}_1, \tilde{c}_2)$ is required for implementation of $(\tilde{c}_1, \tilde{c}_2)$. 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. $ln\left(\frac{\tilde{c}_2}{\tilde{c}_1}\right) < 0$
$\delta \leq \delta^*(\tilde{c}_1, \tilde{c}_2)$ is required for implementation. In this range, a higher δ can be substituted for by a lower η. (See Figure 3.)

Case 3: $\tilde{c}_2 = \tilde{c}_1$, i.e. $ln\left(\frac{\tilde{c}_2}{\tilde{c}_1}\right) = 0$
In this case, δ is uniquely determined as $\delta = \delta^*(\tilde{c}_1, \tilde{c}_2)$, and no substitution is possible.

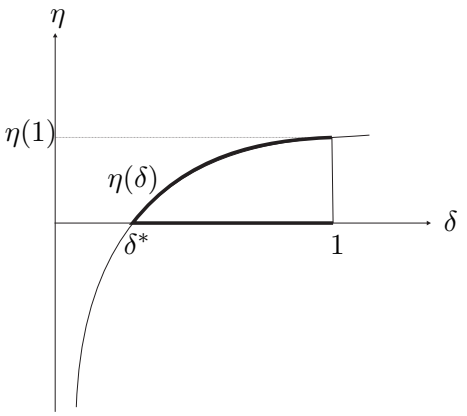

Figure 2: Case 1: $\tilde{c}_2 > \tilde{c}_1$

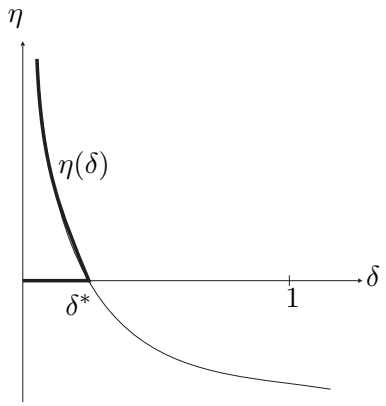

Figure 3: Case 2: $\tilde{c}_2 < \tilde{c}_1$

In Figures 2 and 3 the solid lines describe the combinations of δ and η that all implement the given allocation $(\tilde{c}_1, \tilde{c}_2)$. For the both extreme cases with either $\eta = 0$ or $\delta = 1$ comparison of the two figures in particular yields the following observation:

On the one hand, every consumption profile $(\tilde{c}_1, \tilde{c}_2)$ on the transformation curve becomes a welfare maximum by letting $\delta = \delta^*(\tilde{c}_1, \tilde{c}_2) < 1$ and $\eta = 0$, i.e. by having a time discount, but no inequality aversion. On the other hand, $\delta = 1$, i.e. no pure time

[8] It is, however, a rather complicated exercise to derive the Ramsey equation from (11). See Dasgupta (2001), p. 18, and Creedy (2006) on this.

preference, is only compatible with the selection of some $(\tilde{c}_1, \tilde{c}_2)$, if $\tilde{c}_2 > \tilde{c}_1$, i.e. in case 1. Then taking $\eta(1)$ as depicted in Figure 2 will do the job. In this way every $(\tilde{c}_1, \tilde{c}_2)$ on the transformation curve with $\tilde{c}_2 > \tilde{c}_1$ can be implemented with parameters $\delta = 0$ and $\eta = \eta(1)$.

Therefore, with regard to possible choices of δ and η, there is an asymmetry between case 1 and case 2: Making choices by δ instead of η gives more flexibility which, however, does not seem to be an advantage, if another normative postulate comes into play. So it is widely accepted that economic development over time should be sustainable, which, according to the usual definition, is to mean that utility and consumption should not deteriorate over time.[9] Following this idea, we call a consumption profile $(\tilde{c}_1, \tilde{c}_2)$ *sustainable*, if $\tilde{c}_2 \geq \tilde{c}_1$, i.e. it lies on the segment BC in Figure 4. Then our considerations lead to the following result:

PROPOSITION 1 In a productive economy a consumption path $(\tilde{c}_1, \tilde{c}_2)$ is sustainable with $\tilde{c}_2 > \tilde{c}_1$, if and only if it can be implemented by a social welfare function $W(c_1, c_2)$ with $\delta = 1$ and $\eta > 0$.

Given some positive degree of inequality aversion η, sufficiently small discount factors δ, however, would produce non–sustainable paths in segment AB in Figure 4. A sustainable path $(\tilde{c}_1, \tilde{c}_2)$ can only be implemented if $\delta > \delta^*(\tilde{c}_1, \tilde{c}_2)$.

If one adopts sustainability as an ethical objective, these considerations have the following important implications:[10]

- If the social planner treats generations equally, i.e. $\delta = 1$, and is inequality averse, a path that maximizes intertemporal social welfare is always sustainable. Allowing for positive time discount $\delta < 1$, this is obviously not the case, such that varying only η protects *future* generations in any case.

- Varying of η is flexible enough to pick out every sustainable path $(\tilde{c}_1, \tilde{c}_2)$ with $\tilde{c}_2 > \tilde{c}_1$ such that the social planner needs not falling back upon pure time discount to protect the interests of the earlier generation.

Therefore, we conclude that not only from the viewpoint of time neutrality as an ethical axiom, but also from the viewpoint of sustainability, it is clearly preferable (and completely sufficient) to bring about the desired balance between interests of the two generations by having inequality aversion and not by discounting utility.

This confirms that, defining intertemporal social preferences that reflect the concerns of intertemporal fairness, the focus should be on the parameter η. This gives a further support for the approach taken by the Stern Report. The next logical step then is to inquire what levels of η appear to be reasonable. In the following section, we therefore first give a review on the empirical and experimental studies that have been carried out to determine η, and to which the Stern Review casually refers[11] to justify its specific choice of $\eta = 1$.

[9] 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.

[10] For a generalization to multi and infinite period setting see Asheim & Buchholz (2003). In this extended framework, constancy of η can no longer be assumed.

[11] The Stern report draws e.g. on Pearce & Ulph (1999).

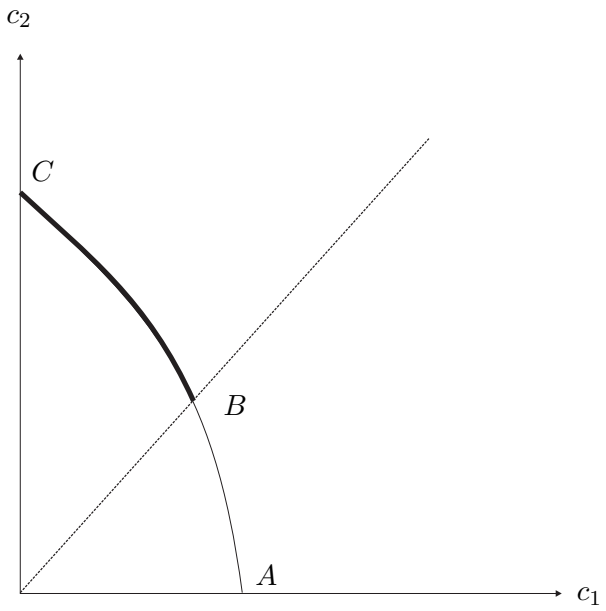

Figure 4: Result

3 Empirical studies on the size of η

There is considerable confusion about the "correct" value of η that should be used in such cost–benefit analysis as undertaken by the Stern Review. So, in his comment on the Stern Report, Weitzman (2007*a*) speaks of $\eta = 2$ as his "own rough point–guesstimate of what most economists might think are decent parameter values" (p. 707) for the Ramsey equation. We think that the notion "guesstimate" reflects well the uncertainty with respect to η.

There are various, conceptually rather different approaches to determine η by reference to 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. So, earlier work by Glejser et al. (1977) showed that people exhibit risk aversion, the degree of which is very sensitive to microeconomic factors. Concerning the specific value 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. On the other hand, the median of the relative risk aversion parameter η found by Johansson-Stenman et al. (2002) lies between 2 and 3.

A caveat of measuring the concavity of agents' utility functions is that actually two concepts are mixed up. Concavity captures both risk aversion and inequality aversion, and, although both concepts have similar implications for the society an agent desires to live in, their underlying ethical content differs considerably. 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.

In a recent study that partially also relies on the leaky bucket approach, Pirttilae & Uusitalo (2007) use representative surveys, in which questions on the actual real–world

economic situations were asked. One could argue that this type of questionnaire is likely to reveal attitudes towards inequality in a more realistic way than laboratory experiments. 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 hypothetical 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 seem to be highly sensitive to the type of question asked and to the environment in which the survey or experiment is conducted.

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, 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 when evaluating the costs and benefits of public projects. 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

$$-ln(1 - T'(y)) = \eta \cdot ln\left(\frac{y}{y - T(y)}\right) \tag{13}$$

where y denotes income and $T(y)$ is the income tax schedule (see Cowell & Gardiner (1999) for an explanation of (13)). 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 term), however, is not generally accepted. There are serious doubts because 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 would yield completely different results such that "scepticism" to the usefulness of these estimates seems to be warranted (Creedy (2006), p. 15).

But there is also a much deeper problem with these empirical studies. So, one has to carefully distinguish between individuals' attitude 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 measures 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. to what extent a social planner allows distributional concerns to affect policy decisions, and in that sense it reflects how the world *ought to be*. The Stern Report in its general part (with reference to Arrow (1995)) underlines the distinction between a "descriptive" and a "prescriptive" approach (Stern (2006), p. 47). The important link between the two concepts is that in democratic societies the government's attitude will

(or should) reflect voters' preferences. Nevertheless, the empirical studies on η represent just one possibility to specify η and the values obtained in this way are not normatively compelling. Beyond these problems at the methodological level, the various studies do not provide a unique value for η but at most delimit a rather wide range for η–levels. So much space is left for the choice of η.

4 Ethical axioms for determining the size of η

4.1 Framework

We now aim to show not only empirical studies but also some simple ethical axiomatics my be useful to delimit the interval of reasonable values for the inequality parameter η. Since the underlying normative requirements reflect some minimum fairness concerns for the distribution among generations, they should hold even in the most simple environment. As above, we therefore consider the case with two generations $t = 1, 2$ of equal size but we now assume a constant marginal rate of transformation $m > 1$ between consumption c_1 of the first generation and consumption c_2 of the second generation. Hence, the transformation curve is defined by

$$G(c_1, c_2) = c_1 + \frac{c_2}{m} = y \tag{14}$$

with y being the exogenously given income.

Maximization of $W_{\eta,1}(c_1, c_2)$ as given by (10) with respect to (14) yields the social welfare maximum $(c_1(m), c_2(m))$ where

$$c_1(m) = \frac{m\, y}{m + m^{\frac{1}{\eta}}} \tag{15}$$

$$c_2(m) = \frac{m^{\frac{1+\eta}{\eta}}\, y}{m + m^{\frac{1}{\eta}}} \tag{16}$$

It can easily be verified, that

$$c_1'(m) = \frac{\partial c_1}{\partial m} = \frac{m^{\frac{1}{\eta}} \left(1 - \frac{1}{\eta}\right)\, y}{\left(m + m^{\frac{1}{\eta}}\right)^2} \tag{17}$$

$$c_2'(m) = \frac{\partial c_2}{\partial m} = \frac{m^{\frac{1}{\eta}} \left(m^{\frac{1}{\eta}} + \frac{m}{\eta}\right)\, y}{\left(m + m^{\frac{1}{\eta}}\right)^2} \tag{18}$$

showing, how the consumption possibilities of both generations react to changes in the productivity parameter m given η. In the following subsection, we will make use of these results to derive the implications of some simple fairness postulates. This is the usual procedure in ethical social choice theory. Put in another way, "hypothetical thought experiment[s]" (Stern (2007), pp. 4-5) are carried out asking which values of η will produce the results that are desired according to some normative criteria. In this way, ethical judgement becomes more transparent and substantiated.

4.2 Postulate A: Protecting the interests of earlier generations

In a productive economy, as explained in a previous section an adequate choice of η avoids excessive savings and thus impoverishment of the earlier generation if the productivity

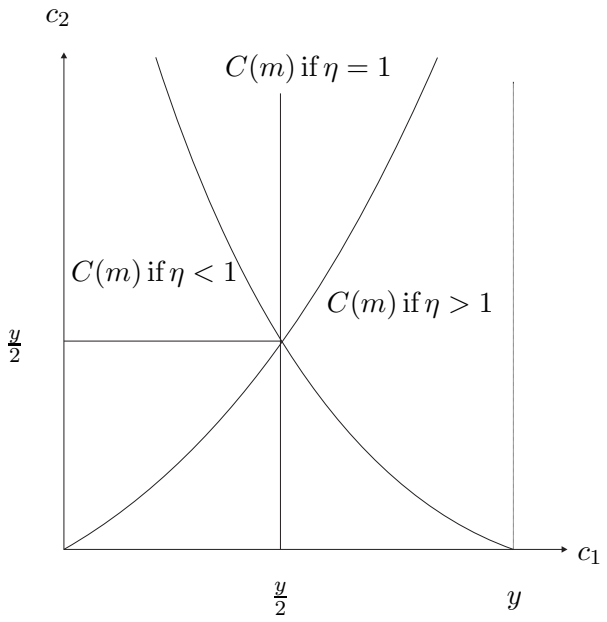

Figure 5: Consumption paths for different η–values.

parameter m is given. We now want to extend this basic idea to the effects that *changes* of m have on both generations. As a normative postulate, this is to mean that the earlier generation should not – under the pressure of the utilitarian maxim – have to suffer when productivity increases. Most people would readily agree that the Pareto principle should also hold in this situation. In a world of uncertainty, this would also imply insurance of the earlier generation, if there is the *risk* of a productivity increase.

Postulate A: No generation should attain a lower consumption level in the welfare maximum when the productivity parameter m increases.

Which degree of inequality aversion is required to fulfill this postulate can directly be read from equations (17) and (18). Clearly, $c_2'(m) > 0$ is always given. However, $c_1'(m) > 0$ holds if and only if $1 - \frac{1}{\eta} > 0$, i.e. $\eta > 1$. This directly leads to the following results.

Proposition 2 : The postulate A is fulfilled in our setting, if and only if $\eta > 1$.

A sufficiently high inequality aversion thus proves to be necessary and sufficient to protect the interests of generation 1 and to avoid its expropriation when there is technical progress, i.e. m increases. In contrast, if we had $\eta < 1$, the first generation's consumption would even go to zero with productivity m going to infinity. For $\eta > 1$, as follows directly from (16), $c_1(m)$ instead approximates total income y for m going to infinity.

Figure 5 depicts two consumption paths $C(m) = (c_1(m), c_2(m))$ for the two situations, i.e. for $\eta < 1$ and for $\eta > 1$. Note that for $\eta = 1$ consumption $c_1(m)$ in the first period is constant and equal to $\frac{y}{2}$ irrespective of m, so that generation 1 neither gains nor looses with changes in productivity.[12] Therefore, we can conclude, that in our simple

[12]The value $\eta = 1$ would also be obtained by an "as–if"–bargaining process between the two generations. For this result, the cooperative bargaining games by Nash or Kalai–Smorodinski can be applied, by choosing

two–period setting $\eta = 1$ is a *lower bound* for inequality aversion, if one wants to avoid the counterintuitive effect that productivity increases reduce earlier generations to poverty.[13] In the infinite period setting, $\eta > 1$ is even required for a more technical reason, because combining $\delta = 1$ and $\eta \leq 1$ would imply diverging utility sums such that the the utilitarian social welfare function would not be directly applicable. In the next two subsections, we will show how – by applying additional equity criteria – even specific values for the inequality aversion parameter η can be obtained.

4.3 Postulate B: Non–envy in the absolute sense

In the economic literature, there is a tradition of applying *non–envy criteria* (in the sense of Foley (1967), Kolm (1972, 1998) and Varian (1974)) to identify allocations, that the concerned individuals would consider as being equitable.[14] The idea of this approach is that some agent i is put in the shoes of some other agent j and vice versa, such that no exogenous arbitrator is required. If then none of both agents would want to interchange his position with the position of his counterpart, the underlying allocation is considered as being *fair* by both agents.

The direct application of the non–envy principle to an intergenerational allocation $(\tilde{c}_1, \tilde{c}_2)$ leads to the following condition, that is based on the assumption that both generations compare their absolute levels of consumption.

Postulate B: Generation 1 considers the allocation $(\tilde{c}_1, \tilde{c}_2)$ as *absolute envy–free* if $\tilde{c}_1 \geq \frac{\tilde{c}_2}{m}$. Generation 2 considers the allocation $(\tilde{c}_1, \tilde{c}_2)$ as *absolute envy–free* if $\tilde{c}_2 \geq m\,\tilde{c}_1$.

An allocation is then called *fair in the absolute sense* if it is considered as envy–free in the absolute sense by both agents. Postulate B clearly implies that $\tilde{c}_2 = m \cdot \tilde{c}_1$ has to hold in every allocation that is fair in the absolute sense.

The motivation for Postulate B is as follows: Generation 1 comparing her consumption level $\tilde{c}_1$ with that of generation 2 according to Postulate B takes into account, that the equivalent of $\tilde{c}_2$ that would actually be attainable for her amounts to $\frac{\tilde{c}_2}{m}$, given the loss of consumption entailed by shifting consumption from period 2 to period 1. A similar reasoning applies to generation 2. Moreover, in an allocation that is envy–free in the absolute sense no generation makes use of a higher share of the exogenously given income y, so that both generations have *equal claims* to the resource endowments. Demanding equality of resource use gives a further motivation to Postulate B.

We will show now that all allocations $(\tilde{c}_1, \tilde{c}_2)$ that – given some productivity parameter m – are fair in the absolute sense and feasible, can be implemented by a social welfare function that is based on an isoelastic transformation function with $\eta = 1$.

Proposition 3 Let $(\tilde{c}_1, \tilde{c}_2)$ be an allocation that is feasible given some $\tilde{m}$ and some income level $\tilde{y}$. Then, $(\tilde{c}_1, \tilde{c}_2)$ fulfills Postulate B if and only if it maximizes $W_{1,1}(c_1, c_2) = ln\, c_1 + ln\, c_2$ given $\tilde{m}$ and $\tilde{y}$.

$(0, 0)$ as the threat point.

[13] This confirms Weitzman (2007*a*), p. 707, who states – without further explanation – that $\eta = 1$ is "the lowest lower bound of just about any economist's best–guess range."

[14] Invoking a non–regret condition in the context of intertemporal valuation is a somewhat similar idea and is suggested by Quiggin (2006), p. 11.

Proof. A feasible allocation $(\tilde{c}_1, \tilde{c}_2)$ maximizes $W_{1,1}(c_1, c_2)$ given $\tilde{m}$ if and only if

$$\frac{\partial W_{1,1}/\partial c_1}{\partial W_{1,1}/\partial c_2}(\tilde{c}_1, \tilde{c}_2) = \frac{1/\tilde{c}_1}{1/\tilde{c}_2} = \frac{\tilde{c}_2}{\tilde{c}_1} = \tilde{m} \tag{19}$$

The last part of this identity, however, is equivalent to Postulate B what proves the assertion. ■

Varying $\tilde{m}$ and $\tilde{y}$ the set of allocations $(\tilde{c}_1, \tilde{c}_2)$ that is covered by Proposition 3 is equal to the set of allocations $(\tilde{c}_1, \tilde{c}_2)$ which have $\tilde{c}_1 > 0$ and $\tilde{c}_2 > 0$, since, given strictly positive consumption levels, $(\tilde{c}_1, \tilde{c}_2)$ is fair in the absolute sense by letting $\tilde{m} = \frac{\tilde{c}_2}{\tilde{c}_1}$ and thus clearly feasible letting $\tilde{y} := \tilde{c}_1 + \frac{\tilde{c}_2}{\tilde{m}} = 2\,\tilde{c}_1$. Therefore, seeking to implement fair allocations as social welfare optima, Postulate B definitely implies the use of $W_{1,1}(c_1, c_2)$ (or a strictly monotone transformation of it). So Postulate B, from the normative perspective of a non–envy condition, provides a justification for the use of $\eta = 1$ as assumed in the main part of the Stern Report.

It is important to underline that to derive these results no specific assumptions on the social welfare function $W_{\eta,\delta}(c_1, c_2)$, such as additive separability or iso–elasticity, are required. Rather, they are an implication of the non–envy postulate alone.

4.4 Postulate C: Non–envy in the relative sense

In the following, we want to explore the implications of a different interpretation of freedom of envy. So one may argue, that people do care less about absolute consumption, but that they rather compare their *relative position* vis–à–vis the other generation, i.e. their *status*.[15] The non–envy–test then refers to the ratios of consumption levels of both generations whereas the adjustment to the economy's productivity, i.e. to m, remains as before. The following postulate specifies this idea:

Postulate C: Generation 1 does *not envy* generation 2 *in the relative sense*, if

$$\frac{\tilde{c}_1}{\tilde{c}_2} \geq \frac{\tilde{c}_2/m}{\tilde{c}_1} \quad \Rightarrow \quad m\,\tilde{c}_1^2 \geq \tilde{c}_2^2$$

Generation 2 does *not envy* generation 1 *in the relative sense*, if

$$\frac{\tilde{c}_2}{\tilde{c}_1} \geq \frac{m\,\tilde{c}_1}{\tilde{c}_2} \quad \Rightarrow \quad m\,\tilde{c}_1^2 \leq \tilde{c}_2^2$$

An allocation $(\tilde{c}_1, \tilde{c}_2)$ is called *status fair* if it is considered as envy–free in the relative sense by both agents. Postulate C clearly implies that

$$m\,\tilde{c}_1^2 = \tilde{c}_2^2 \tag{20}$$

has to hold in any status–fair allocation $(\tilde{c}_1, \tilde{c}_2)$.

Proposition 4 Let $(\tilde{c}_1, \tilde{c}_2)$ be an allocation that is feasible given some productivity parameter $\tilde{m}$ and some income level $\tilde{y}$. Then, $(\tilde{c}_1, \tilde{c}_2)$ fulfills Postulate C if and only if it maximizes the social welfare function $W_{2,1}(c_1, c_2) = -(c_1^{-1} + c_2^{-1})$ given $\tilde{m}$ and $\tilde{y}$.

[15] For the impact of status concerns on agents economic decisions see e.g. Veblen (1899), Layard (1980), Ng (1987), and more recently Bolton & Ockenfels (2000), Luttmer (2005), Fehr & Schmidt (2006).

Proof. The proof is completely analogous to that of Proposition 3. A feasible allocation maximizes $W_{2,1}(c_1, c_2)$ given $\tilde{m}$ if and only if

$$\frac{\partial W_{2,1}/\partial c_1}{\partial W_{2,1}/\partial c_2}(\tilde{c}_1, \tilde{c}_2) = \frac{\tilde{c}_1^{-2}}{\tilde{c}_2^{-2}} = \left(\frac{\tilde{c}_2}{\tilde{c}_1}\right)^2 = \tilde{m} \tag{21}$$

The last part of this identity, however, is equivalent to Postulate C what proves the assertion. ■

Postulate B thus gives a justification for the use of $\eta = 2$ in evaluation over time which lies in that range that is preferred by many critics of the Stern Report.

Combining Postulate B with Postulate C suggests that, from the non–envy perspective, some mixture between the social preferences described by Proposition 3 and Proposition 4 might seem reasonable. Thus η would have to lie between 1 and 2.

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 Report'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 report 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 at the conceptual level differs very much. In the following, we concentrate our discussion on the arguments raised by Dasgupta (2006, 2007) on the one hand and by Nordhaus (2006) on the other, which are both typical for two strands of criticism.[16]

A rather modest objection is only concerned with the specific choice of the inequality aversion parameter η, while, in principle, accepting the ethically based social welfare function approach and the choice of a small value for the pure time preference parameter ρ. So Dasgupta (2006, 2007) 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). But in contrast to Stern, Dasgupta (2007) prefers a value for η that exhibits more inequality aversion and thus, in a productive economy, is more in favor of the present generation. Looking at a simple growth model with a time–invariant constant returns to scale technology, he shows that choosing $\eta = 1$ as in the main part of the Stern Report would imply implausibly high savings rates. In order to give earlier generations more protection and to obtain more equally distributed intertemporal consumption paths, some higher value for η is required. Dasgupta (2007) suggests the use of a η somewhere in the range between 2 and 4, but except some scant reference also to experimental studies and to the higher plausibility of the entailed savings rates, he does not provide justifications.[17] Rather, he concedes (p. 15-16) that we have "very little understanding of what η implies for intergenerational saving." To support Stern's and Dasgupta's common position and

[16] Other critics are not so explicit concerning the direction of their objections or are mainly concerned with specific issues, i.e. Weitzman (2007a, 2007b) focusses on problems of risk and uncertainty in evaluation over time.

[17] Similar choices of η are, also based on considerations of plausibility, recommended e.g. by Gollier (2006), Arrow (2007) and Weitzman (2007*a*).

to enhance the understanding of η's role in evaluation over time, has been the main motivation for our analysis in the previous sections.

Another attack of prominent economists against the Stern Report (see above all Nordhaus (2007) and Weitzman (2007*a*)) goes much deeper, as it casts doubt on the *ethically motivated* use of social welfare functions as such. It is an implicit presumption of this fundamental criticism that applying exogenously defined normative criteria to assess the intertemporal distribution of costs and benefits does not conform to the paradigm of mainstream economics, i.e. to "methodological individualism." 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. Especially concerning the relative valuation of future versus present consumption that are at stake in the context of climate change, these individual preferences are revealed on the capital market by the interest rate, which, therefore, should also guide political actions. Moreover, economic and political decisions today are exclusively made by currently living people and thus can only reflect their preferences (which, however, are not purely egoistic but also include altruistic feelings towards their descendants and thus to future generations). Therefore, building a policy–oriented analysis on normative judgements is not only hard to justify from the economist's point of view, but also of no practical relevance. So it is held that an ethical "Nirvana approach" lies at the heart of the Stern Report (Sinn (2007)).

This basic criticism is obviously right insofar as the social welfare function used in the Stern Review cannot be determined in an objective way – which is well admitted in the Report itself. What people (including the authors of the Report) think to be desirable for the world society as a whole in the end is always a matter of personal taste that should not be forced upon other people. This is an integral part of a liberal democracy which is accepted by any serious economist.

A quite different matter, however, is that it is legitimate to examine whether the economic process satisfies certain objectives, that – for the sake of the investigation – are set by the analyst and persons who, according to their tastes, share these objectives. Hence, a firm owner might want to know, whether he will, by following some business strategy, has a chance of becoming a leader in his market. At the social level, people might be interested to know whether a certain environmental policy can be expected to maximize undiscounted aggregate welfare of all individuals living from now until the year 2525 ('if man is still alive'). Since people have preferences that, to some extent, show altruism towards posterity and conservation of natural assets (otherwise climate change would not have become a political issue at all) they, as voters in a democracy, ask experts like Stern to carry out scientific studies in which intergenerational equity is a matter of concern. Dealing with intergenerational distribution in a systematic (and not at all unconditional) way, the Stern Report is far away from expressing solely "the lofty vantage point of the world social planner, perhaps striking the dying embers of the British empire" (Nordhaus (2007), p. 691). Rather the Stern Report provides some further input to the public discourse, and its proposals still need the support of a democratic majority to be transformed into binding political decisions.[18]

In total, the fundamental condemnation of the Stern Review's approach to intergener-

[18] A not quite harmless semantic problem, however, arises if (as in the Stern Report) the non-achievement of some subjectively set normative standard is called "market failure". Most economists tend to reserve the notion to coordination failures among economic subjects actually participating in market transactions which is at odds with the maximization of aggregate welfare of different generations, most of which have not yet come into existence. The Stern Report should have been more cautious here.

ational cost–benefit–analysis is not only much exaggerated in tone but also not warranted from the perspective of conventional economic methodology. Clearly the starting point of Stern's analysis is a subjective value judgement which, however, is not quite uncommon for many economists and ordinary people ('sustainability' if you like) which is made transparent in the Report. Adhering to individualism, one should not accuse Stern and his clients for taking their personal beliefs as the well–documented benchmark of the analysis. The existence and legitimacy of a subjective "Erkenntnisinteresse" is not to be denied just from the liberal standpoint.

But the problem with the fundamental critics is not only that they partially miss the point, but also that their approach has deficiencies of its own. First of all, there is serious doubt that the market interest rate in fact is an adequate expression of the agents' intertemporal preferences just when future generations are involved. There are market imperfections as, e.g., a divergence between agents' economic and political preferences (Nyberg (2000)), unduly high personal risk premia, imperfect property rights (Sinn (2007)) or Sen's famous "assurance problem" (Sen (1967)), that may prevent intergenerational altruism from materializing by isolated transactions in the market place.[19]

From the methodological viewpoint it is, however, much more serious that the fundamental critics give the false expression that climate change policy is possible without ethical considerations at all and so – pretending that "economics is an ethic–free zone" (Broome (2005), p. 80) – throw the child out with the bath. As soon as actions of some people ("the current generation") affect other defenseless people that cannot take part in the decision process today ("the future generations") either one adopts complete laissez–faire ("Let them alone!")[20] or one has to look for some behavioral standards and norms. Tackling problems of distribution between generations in a serious way involves that not yet born people receive consideration in their own right. (See on this Padilla (2002).) Here ethics unavoidably comes into play because its classical task is to *device* (in liberal thinking clearly not to *prescribe* in an ultimate way) rules of acceptable behavior towards others and – in the context of economics – to reflect about distributional values. Thus "we cannot help being ethical from the start" (Broome (2005), p. 81). Ethical judgements, however, are never free of some arbitrariness, which may cause some discomfort for economists as scholars of an empirical science. Observing the market cannot take away from us the, to some degree elusive, ethical reflection if we have some interest in the well–being of posterity. Only with the help of some normative yardstick it becomes possible at all to judge the well functioning of the market mechanism and, if necessary, to design collective action to protect future generations.

The fundamental critics of the Stern Report do not seem to take this basic ethical issue very serious, but directly jump into an, at a closer look not well–grounded, pragmatism. So, e.g., the possible ethical content of the calibration procedure which determines the parameters δ and η of the social welfare function, making them fit to current interest rates ini the framework of computational general equilibrium (CGE) models remains in the dark (Nordhaus (2007), pp. 692–693). Moreover, the projection of interest rates over a longer time horizon is, from these critics' perspective, somewhat inconsistent, because

[19]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*).

[20]So Quiggin (2006), p. 14, criticizes Nordhaus for adhering to such a position by using, in earlier studies, a pure discount rate of 3 % since this is "tantamount to saying that the future (certainly anyone more than two generations away from us) can go to hell."

after 100 years or so yet unborn people will make the decisions on the capital market that then determine the level of the interest rate. So one cannot claim that the analysis is only based on actually revealed preferences. Another main point of concern is that not very much reason is given for employing a relatively high value for the pure time discount rate ρ. Nordhaus (2007, p. 696) only uses a thought experiment showing that a discount rate ρ close to zero would produce a "bizarre result", which is nothing more than another version of the old (and refutable) 'excessive savings' argument. Ethical reasoning on the size of ρ[21] is thus substituted by ad hoc assumptions, that are based on some mixture of plausibility considerations and reference to empirical facts. Overall, it is not Stern but some of his fundamental critics who are in danger of confounding objective facts with subjective values.[22] Against this background, a major merit of the Stern Review at the methodological level is that it brings the unavoidable ethical underpinning of climate change policy to the fore. As it should be part of any economic analysis the underlying value judgements are laid down in a transparent way so that everyone immediately knows what is going on and that ethically sensible critics, as Dasgupta (2007) or Beckermann & Hepburn (2007), can set in directly confronting these specific assumptions. Perhaps, the Stern Review has also contributed to revitalize the general discussion on the relationship between ethics and economics, going far beyond the issue of climate change policy.

At the end of his argument Nordhaus (2007) comes somewhat closet to Stern's position, when he shows, that by assuming $\rho = 0.001$ and $\eta = 3$ for 'run 3' of his revised DICE model, he is able to produce time paths for interest rates and implicit carbon prices which are very similar to the 'run 1' where $\rho = 0.015$ and $\eta = 2$ had been supposed. This turn of argument is, at the same time, reassuring and irritating. On one hand, it is reassuring because Nordhaus, to some extent, vindicates a basic message of the Stern Report, i.e. that, in principle, one can do without pure time discounting and instead choose η appropriately. The problem is then reduced to the choice of η which is also the main point of Dasgupta's criticism and of our paper. On the other hand, it is irritating, because there is some contradiction to Nordhaus' elsewhere stated belief, that a relatively high value of ρ is indispensable. Overall understanding would have been facilitated if Nordhaus had directly said that – in his opinion – Stern simply has chosen the wrong η, i.e. $\eta = 1$ instead of $\eta = 3$. So again, we can conclude from these reflections that the discussion on valuation over time should first of all be on η, its adequate level and possible methods to determine it. Otherwise, too much hot air might cause a tempest in the teapot and an unnecessary confusion over the basic conceptual questions.

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 re-

[21] To defend a value of ρ that – also under conditions of certainty – lies significantly above zero (as Beckermann & Hepburn (2007), pp. 198-202) some "agent relative ethics" in the human sense can be applied.

[22] In a comment on his critics, Stern (2007), p. 14, has, in a very clear way, denounced the so called "revealed ethics approach": "But let us take on directly the question of whether it could ever be reasonable to think that markets could reveal social values for use in discounting benefits into the far future. Our response is a clear 'no'. We cannot and should not avoid taking on directly the basic ethical discussion. Market observations will not solve the problem for us."

cent 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 definitely excluded, which, in this paper, has been shown in an elementary two period model. 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 (gradual) 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 end more recently 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 should serve as a sound basis for decisions, when normative criteria for the ethically appropriate treatment of other persons, i.e. future generations, can be found. We, therefore, introduced some simple normative axioms in order to define the relevant range of η, as it is common in ethical social choice theory. The main result of these considerations has been that setting $\eta = 1$, as used in the main part of the Stern Report, is an extreme assumption. Rather, $\eta = 1$ is a lower bound for reasonable values of inequality aversion when excessive savings in the face of productivity changes is to be avoided. Adopting a status non–envy condition we may, as in this postulate, infer e.g. a value of $\eta = 2$. Combining absolute non–envy with relative non–envy a range between 1 and 2 would be obtained, which, fortunately, does not differ very much from the results of the empirical studies.

Postulating the use of some $\eta \geq 1$ is well in line with most of the critics of the Stern Report. Some of the objections raised against the Report, however, go far over the top as they completely deny the ethical intention underlying Stern's approach to intertemporal cost–benefit–analysis. These critics fail to provide a convincing alternative and stick to a pragmatic approach, i.e. calibration of parameters in the CGE–framework, which, from the normative perspective is not adequately founded. To reconcile this pragmatism with a sound ethical analysis may be an important future task not only in the field of climate change.

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