Climate Policies Deserve a Negative Discount Rate

Marc Fleurbaey

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Abstract

Eric A. Posner and David Weisbach1 advocate discounting the future impacts of climate policies at the market rate of return in order to take account of opportunity costs; however, they suggest that the desirable amount of investment may have to be decided on ethical grounds.2 We argue that deriving the discount rate from a social welfare objective is preferable to the market rate because it both accounts for opportunity costs and suitably determines the amount of investment in climate policies that is desirable for future generations. Moreover, extending Martin Weitzman’s3 and Christian Gollier’s4 results on discounting under uncertainty, we show that for evaluating the long-run impacts of climate policies, a negative discount rate may be justified. This is due to the uncertainty of future growth and the fact that such policies have greater returns in bad climate scenarios. The distributive impact of such policies also justifies a low discount rate if the poorest populations are the most vulnerable to climate change. Finally, we argue in favor of going beyond classical utilitarian calculus in order to better incorporate prioritization of the worst off into the evaluation of climate policies.

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1 Eric A. Posner and David Weisbach, Climate Change Justice (Princeton 2010).
2 Id at 161–62 and 167–68.
3 Martin L. Weitzman, Why the Far-Distant Future Should Be Discounted at Its Lowest Possible Rate, 36 J Envir Econ & Mgmt 201, 201–02 (1998).
I. Introduction

Climate policies are costly for the present generation, yet will benefit future generations in centuries and millennia to come. It is incredibly hard to assess whether the benefits outweigh the costs with such faraway horizons. Cost-benefit analysis is generally used to assess the returns of public investments over a decade or two, a relatively short horizon over which individual time preferences and market rates provide useful guidelines. The discount rate is a convenient tool that translates future values into their equivalent present value. With a 3 percent rate, for instance, $1 million in ten years is worth about $744,000 ($1,000,000/1.03^{10}) today.

For long-term, intergenerational tradeoffs, experts are hesitant to use the same individual and market-rate time preferences because they imply discounting future consumption flows at a rate that makes dramatic changes in two generations look almost negligible in present value. Since the 2007
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publication of the *Stern Review*, the discount rate has therefore been at the center of heated discussions about climate policies.

In the very long run, the discount rate makes a huge difference in the cost-benefit evaluation of policies. Table 1 shows the minimum return that a $1 investment for the future must have in order to be considered better than consuming $1 now, depending on the discount rate that is adopted and the horizon. The 1.4 percent discount rate is advocated by the *Stern Review*, but later Nicholas Stern suggested that 1.5 percent to 5 percent might be a better range.

The table shows that this hesitation is not innocuous. Obviously, adopting a much higher discount rate, as recommended by Nordhaus—around 5.5 percent—has even more extreme consequences.

<table>
<thead>
<tr>
<th>Time horizon (years)</th>
<th>Required return on $1 investment, by discount rate ($)</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>$2.00</td>
<td>1.4%</td>
</tr>
<tr>
<td>100</td>
<td>$4.02</td>
<td>2.7%</td>
</tr>
<tr>
<td>200</td>
<td>$16.13</td>
<td>3.57%</td>
</tr>
<tr>
<td>500</td>
<td>$1,044</td>
<td>584</td>
</tr>
<tr>
<td>1000</td>
<td>$1,091,327</td>
<td>340,791</td>
</tr>
</tbody>
</table>

*Legend:* With a 1.4 percent discount rate, a $1 investment today must yield at least $4.02 in one hundred years; with a 2.7 percent discount rate, the number jumps to $14.36, which is 3.57 times greater.

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8 Nicholas Stern, *The Economics of Climate Change*, 98 Am Econ Rev Papers & Proceedings 17, 19 (2008). This is mostly about the value of parameter $p$ (defined in Section II of this paper). This parameter takes value 1 in the *Stern Review* whereas Stern later considered it could go up to 2. As noted by Posner and Weisbach, if one inserts this upper value into the formula of the discount rate that yields the 1.4 percent figure in the *Stern Review*, one obtains 2.7 percent instead. Posner and Weisbach, *Climate Change Justice* at 158 (cited in note 1).


10 Id at 694.
The thesis defended in this Article is that using a negative discount rate to evaluate climate policies may be justified. This conclusion follows from two important steps, each of which is an interesting separate thesis. First, different policies should be evaluated with different discount rates, depending on which populations are impacted. Second, in the long run, only the worst scenario for the worst off fraction of the population counts.

Our thesis is at odds with Posner and Weisbach’s conclusion in Chapter 7 of Climate Change Justice,\(^\text{11}\) even though we share the same premises: impartiality between generations, compatibility with ethical principles, and taking opportunity costs into account. Posner and Weisbach advocate using the market interest rate as the discount rate for the selection of particular projects. It is an interesting question to understand how our similar premises can deliver very different practical conclusions. We disagree primarily on how to make use of the discount rate. For us, it is a tool to assess and compare different consumption paths or money flows in terms of net present value; for Posner and Weisbach, it serves to take into account the opportunity cost of the investment.\(^\text{12}\)

In Section II of this Article we introduce the basic methodology of discounting. In Section III we examine the main objections to it that are encountered in the debate about discounting, and discuss agreements and disagreements with Posner and Weisbach about how to assess these arguments. Then in Sections IV and V we extend the discounting methodology to incorporate risk and intragenerational inequalities. As far as risk is concerned, we offer a reformulation and extension of the well-known Weitzman–Gollier arguments\(^\text{13}\) in favor of using a small, possibly negative rate in the context of risk. Section VI derives our core arguments for negative discount rates from the results of Sections IV and V. For the sake of an easy presentation, the bulk of the analysis is formulated in the context of utilitarian reasoning, but we explain in Section VII why the utilitarian approach must be replaced with a more promising approach and how this can affect the debate about the discount rate. Section VIII concludes.

II. THE METHODOLOGY OF DISCOUNTING

In this section we present the basic methodology for calculating the discount rate. As noted in the introduction, for simplicity we provisionally adopt

\(^{11}\) Posner and Weisbach, Climate Change Justice at 167–68 (cited in note 1).

\(^{12}\) Id at 147.

\(^{13}\) See generally Weitzman, 36 J Envir Econ & Mgmt 201 (cited in note 3); Gollier, 85 J Pub Econ 149 (cited in note 4).
the utilitarian way of defining social welfare.\textsuperscript{14} As a consequence, what we present in this section is essentially identical to the approach adopted in the \textit{Stern Review}.\textsuperscript{15}

More precisely, we assume that social welfare can be computed as the sum of the utility of all individuals, giving the social welfare function

\begin{equation}
W = \sum_i U(c_i),
\end{equation}

where $U(\cdot)$ is the utility function and $c_i$ is the consumption level of individual $i$. What is important about this approach is that the function $U(\cdot)$ is assumed to be the same for all individuals, which means in particular that there is no preference for earlier generations relative to future generations because the contribution of an individual’s utility to total social welfare is unaffected by the time period in which that individual lives. While the \textit{social welfare function} $W(\cdot)$ embodies the evaluator’s neutrality about the distribution of utility among particular individuals, the \textit{utility function} $U(\cdot)$ captures the preferences of the evaluator about inequalities in \textit{consumption}—which means that, in terms of consumption, the approach is prioritarian rather than utilitarian.\textsuperscript{16} We will sometimes adopt a special functional form that is common in the economic literature:\textsuperscript{17}

\begin{equation}
U(c) = \frac{1}{1-\rho} (c^{1-\rho} - \hat{c}^{1-\rho}),
\end{equation}

where $\rho$ can be interpreted as a coefficient of aversion to consumption inequality,\textsuperscript{18} and $\hat{c}$ is the minimum level of consumption that is required to make

\textsuperscript{14} For a very brief explanation of the utilitarian welfare function, see Stern, \textit{The Stern Review} § 2.1 at 26–29 (cited in note 5).

\textsuperscript{15} Stern, \textit{The Stern Review} § 2A.2 at 52 (cited in note 5).

\textsuperscript{16} The utilitarian approach maximizes the sum whereas the prioritarian approach gives priority to benefiting the badly off. Derek Parfit, \textit{Equality or Priority?}, in Matthew Clayton and Andrew Williams, eds, \textit{The Ideal of Equality} 81, 81–125 (Macmillan 2000) (proposing a further distinction between the prioritarian approach, which gives priority to the \textit{badly off}, and the egalitarian approach, which gives priority to those who are \textit{worse off than others}. But this distinction is not important here).

\textsuperscript{17} See, for example, Stern, \textit{The Stern Review} at 52 (cited in note 5); Nordhaus, 45 J Econ Lit at 691 (cited in note 7).

\textsuperscript{18} Stern, \textit{The Stern Review} at 184 (cited in note 5), and Nordhaus, 45 J Econ Lit at 691 (cited in note 7) consider this parameter as an empirical magnitude that can be estimated from individual attitudes to risk or to consumption smoothing over the life cycle. In the first sections of this Article we only view it as embodying the social evaluator’s attitude to inequalities in consumption. Such an ethical attitude need not be related in any way to the population preferences about risk and consumption. Risk preferences will be discussed in Section VII.
utility positive. With this function, the marginal utility of consumption, $U'(c)$, is equal to $c^{-\rho}$, which makes further analysis quite simple.

For the sake of simplicity, we ignore the risk that future generations will not exist. This issue will be introduced later in the Article.¹⁹

Suppose that $c_i$ is reduced by a small amount $\Delta c_i$, and $c_j$, which occurs $t$ periods later, is increased by a small amount $\Delta c_j$. Is this good for social welfare? If the changes are infinitesimal, one can use the marginal utilities to evaluate the changes, and the change in social welfare is then equal to

$$\Delta W = -U'(c_i)\Delta c_i + U'(c_j)\Delta c_j. \quad (3)$$

This can be expressed in units of present consumption by dividing every term by the marginal utility of $c_i$, which gives the net present value (NPV)

$$-\Delta c_i + \frac{U'(c_j)}{U'(c_i)}\Delta c_j. \quad (4)$$

Equating this expression for the NPV of the change in welfare with its discounted value, $-\Delta c_i + \frac{1}{(1+\delta)^t}\Delta c_j$, gives the following formula for the discount rate

$$1 + \delta = \left(\frac{U'(c_j)}{U'(c_i)}\right)^{-1/t} \quad (5)$$

The discount rate is a direct expression of the relative priority of the two individuals (or generations) $i$ and $j$, modulated by the length of time $t$ between the two individuals. If the future individual $j$ is better off than the present individual $i$, the expression is greater than one; that is, the discount rate is positive.

This methodology provides a discount rate that can serve to evaluate small projects. Any project that yields a rate of return greater than the discount rate is beneficial to social welfare. However, for big projects, the marginal utilities are no longer acceptable in the computation and one has to make a direct evaluation of the change in social welfare.

When the marginal utility is equal to $c^{-\rho}$, the formula for the discount rate simplifies to

$$1 + \delta = (1 + g_{ij})^\rho, \quad (6)$$

¹⁹ See Section VII.B.
where $g_{ij} = \left(\frac{c_{ij}}{c_i}\right)^{1/t} - 1$ is the average annual growth rate of consumption between the present and year $t$. When $g_{ij}$ is small, Equation (6) can be approximated by the famous Ramsey formula:

$$\delta = \rho g_{ij}. \tag{7}$$

A reasonable value for inequality aversion is $\rho = 2^{21}$ while a standard estimate for the growth rate is 1.3.\textsuperscript{22} Plugging these values into Equation (7) gives a discount rate of approximately 2.6 percent. (Stern adds a 0.1 percent term due to the risk of extinction of humanity,\textsuperscript{23} but we ignore this term for the moment).

### III. Objections to This Methodology

The discount rate obtained with the methodology introduced in the previous section may be quite different from the market rate, and this has triggered a vivid debate. On one side are those who are happy applying the usual cost-benefit discount rates to long-run policies; on the other are those who think that intergenerational equity requires granting greater consideration to future generations. The debate is described in an influential text\textsuperscript{24} as a confrontation between a descriptive approach and a prescriptive approach, while Posner and Weisbach use the labels “positivists” and “ethicists.”\textsuperscript{25}

Such labels are puzzling because, as Posner and Weisbach write, “in the end, of course, the positivists’ approach is worth nothing unless it can be

\begin{itemize}
  \item Frank P. Ramsey, *A Mathematical Theory of Saving*, 38 Econ J 543, 546 (1928).
  \item Stern, *The Stern Review* at 185 (cited in note 5).
  \item Id at 184.
  \item Posner and Weisbach, *Climate Change Justice* at 149 (cited in note 1).
\end{itemize}
defended on ethical grounds." So, the debate is not so much one between ethics and something else as it is a debate within ethics.

A. Objection That Using Non-Market Rates Is Undemocratic

Proponents of the descriptive approach invoke two ethical arguments. The first is that market rates reflect the preferences of the population, so that it is undemocratic to propose using different rates. The climate economists who propose using lower rates for climate policies are imposing their views on a population that appears to care less about the future than they do. (Gollier, in this issue, actually shows that risk-free market rates are lower than what ethicists propose.) This first argument is unacceptable, but the reasons why it cannot be accepted are far from simple.

There are several mistakes in the argument. First, this reasoning would impose aggregate population preferences on every evaluator. Obviously, there are many views among members of the population. If an evaluator wants to examine a development path with a great concern for the future, there must be some people in the population who share this concern. Even if nobody shares this concern, the evaluator might be right to disagree with everyone else. Just as there is freedom of thought, and just as different political parties can have their own platforms, so too there should be room for economic evaluation that embodies various views about social welfare and the principles of intergenerational equity.

The reply to this objection will certainly be: different economic evaluations may be conducted, but the government, in its decisions, cannot impose idiosyncratic views on the whole population. This is a powerful argument, even though history contains praiseworthy examples of governments imposing

26 Id at 149–50.
28 See Nordhaus, 45 J Econ Lit at 691 (cited in note 7) (criticizing the sort of “Government House utilitarianism”—an arrangement where a utilitarian elite makes decisions based on its own rather than the population’s beliefs—espoused by The Stern Review).
policies contrary to majority opinion (for example, the abolition of the death penalty in France in 1981). But this democratic argument does not imply that the market interest rate should serve as the discount rate. It only requires a democratic debate to take place. This debate will have to address the various arguments underlying the computation of the discount rate. One cannot pretend to know the conclusions of this debate in order to prevent some propositions from reaching the debate. Democratic principles cannot be used to bar some (minimally sound) ethical principles from the forum.

One could still try to argue that the market does tell us something about the population’s preferences about intertemporal tradeoffs. The issue, though, is what that “something” is. Market interest rates are determined jointly by technological possibilities (the productivity of capital) and by the willingness of investors to transfer wealth into the future in exchange for some return. Just like the relative market price of oranges and pears implies that all buyers active on both markets are willing to trade oranges for pears at this relative price, the interest rate indicates investors’ and savers’ common willingness to trade consumption (marginal rate of substitution) across time. This is true, but investors and savers, whose preferences are reflected in the market interest rate, are making decisions to transfer their present wealth to themselves in a few years. If they were asked to transfer wealth to other people living all over the world, in many decades, they might express very different preferences. The financial markets do not ask them this outlandish question, and therefore we cannot pretend that their answer to a very different question is adequate for this purpose. Observe, moreover, that the market interest rate also depends on the distribution of wealth in the population, which has no reason to be particularly democratic.

Even if there were markets in which people could express such preferences (private donations to environmental nongovernmental organizations focused on the climate might be one relevant source of information), it is doubtful that such preferences would be more respectable than the outcome of an outright democratic debate informed by the relevant expertise and considering the best ethical arguments.

In conclusion, if experts like Stern propose a series of reasonable arguments leading to the conclusion that climate policies should be evaluated with a discount rate that is much lower than the market interest rate, they cannot be dismissed as undemocratic and off track. They should be admitted to the democratic debate and their arguments should be carefully listened to (without any guarantee that they will be adopted).

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B. Objection That Non-Market Rates Neglect Opportunity Costs of Investments

The second argument used by the advocates of the market rate is that this rate measures the opportunity cost of resources. This is the main argument considered, and endorsed, by Posner and Weisbach.\(^3\) It is this argument that leads Posner and Weisbach to propose using the market interest rate.\(^3\) This argument is crystal clear. Suppose a climate policy costs $1 today and brings benefits worth $14.40 in one hundred years. According to Table 1, this policy is better than the consumption of the $1 today if the discount rate is 2.7 percent or lower. The objection is that investing the same amount at the market rate, which is supposedly greater, would bring greater benefits in the future. Using a lower discount rate than the market rate is therefore branded as a recipe for choosing dominated policies—policies that either cost more today or pay less tomorrow, or both.

This argument is very simple and extremely powerful. But it aims at the wrong target. More precisely, it relies, in our view, on a misunderstanding of the role of the discount rate. The purpose of the discount rate, as explained in the previous section, is to make consumption levels or monetary values comparable across time. It makes it possible to compute the net present value (NPV) of any change to the status quo. If the NPV is positive, the change is an improvement. But this does not mean that this particular change is optimal. In order to choose the best policy or project, one must compare the NPV (computed with whatever discount rate seems appropriate) of all options, including ordinary market investments. Clearly, with this methodology, if one option costs less today or pays more tomorrow (or both) than another option, it will be deemed preferable, whatever the discount rate.

There is therefore no danger that adopting a lower discount rate than the market rate could induce inefficient (in other words, dominated at each period) choices. It will only imply making different choices among the efficient (in other words, undominated) options. With a lower discount rate, one will choose to invest more for the future, but one will never be tempted to invest at a low rate of return when a higher rate of return is possible. If a business-as-usual investment policy that puts all savings in the financial market brings more benefits to future generations than a mitigation policy aimed at curbing greenhouse gas emissions, even the most devoted disciple of the *Stern Review* will approve it.

\(^{32}\) Posner and Weisbach, *Climate Change Justice* at 146–47 (cited in note 1).

\(^{33}\) Id at 167–68.
To illustrate this point, Table 2 presents four policies, with their undiscounted benefits and their NPV according to two different values of the discount rate. (The 1.4 percent is from the *Stern Review* and 5.5 percent has been advocated by Nordhaus.) Policies A and C are market investments earning 5.5 percent, policy B is a climate policy with impacts equivalent to a 10 percent monetary return, and policy D is a climate policy with impacts equivalent to a 6 percent return. Policies A and B yield returns in one hundred years, while policies C and D pay in five hundred years. The 5.5 percent discount rate enables us to check that climate policies B and D are not dominated by market investments—but is it also helpful for choosing between B and D? Using this higher rate suggests that B, which has impacts of greater value in the shorter term, is preferable to D. But the lower discount rate of 1.4 percent suggests otherwise, while still revealing that these two climate policies are not dominated by the market. It is therefore important to have a good discount rate, not so much to check if the market dominates a climate policy—because any discount rate will do for that limited exercise—but to be able to choose between undominated policies.

**TABLE 2. HOW TO CHOOSE POLICIES WITH VARIOUS DISCOUNT RATES**

<table>
<thead>
<tr>
<th>Policy option (type, average annual rate of return)</th>
<th>A (market, 5.5%)</th>
<th>B (climate, 10%)</th>
<th>C (market, 5.5%)</th>
<th>D (climate, 6%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time horizon (years)</td>
<td>Income stream over time ($)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>-1</td>
<td>-1</td>
<td>-1</td>
<td>-1</td>
</tr>
<tr>
<td>100</td>
<td>211</td>
<td>13,781</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>500</td>
<td>0</td>
<td>0</td>
<td>$4.23 \times 10^{11}$</td>
<td>$4.50 \times 10^{12}$</td>
</tr>
<tr>
<td>Discount rate (per annum)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.40%</td>
<td>51.66</td>
<td>3430.41</td>
<td>$4.05 \times 10^8$</td>
<td>$4.30 \times 10^9$</td>
</tr>
<tr>
<td>5.50%</td>
<td>0.00</td>
<td>64.17</td>
<td>0.00</td>
<td>9.63</td>
</tr>
</tbody>
</table>

**Legend:** Policy A costs $1 today and pays $211 in one hundred years; at a 1.4 percent discount rate, its present value is $51.66; at a 5.5 percent discount rate, its present value is $0.

In conclusion to this point, when Posner and Weisbach write: “even if the ethicists’ arguments are entirely correct, we must still carefully consider the opportunity cost of projects and pick those with the highest returns,” we fully agree, and every reasonable “ethicist” should agree, too. But this does not imply that the market rate of return should be used for the evaluation of projects.

Note that the use of discount rates would be superfluous if the problem were to choose between policies with similar time profiles like policies A and B in Table 2, because their own rates of return can be directly compared. It is only when there are time trade-offs that computing the NPV becomes useful, as in the comparison between policies B and D. (Actually, as we will show later, projects with the same time profile may affect different populations, thus meriting different discount rates, which is equivalent to incorporating social benefits in the computation of their rate of return.)

C. Further Sources of Divergence from Posner and Weisbach

There is another related methodological issue on which we disagree with Posner and Weisbach. They propose using the discount rate in a limited way: “Discounting . . . should be seen only as a method of choosing projects, not as a method of determining our obligations to the future.” This dichotomy is a direct consequence of the tension produced by their idea that one should use the market discount rate for the choice of projects, but nevertheless follow the ethicists’ rate to decide how much to save for the benefit of future generations. In other words, two discount rates would be used in the methodology proposed by Posner and Weisbach, although they do not make this fully explicit (and would perhaps allow for considerations other than standard welfarism to determine how much should be saved). The low discount rate of the ethicists would serve to check if more should be invested overall, whereas the market rate would govern the choice of particular projects to ensure selection of the most efficient options.

There is no need for such a dichotomous methodology. The “ethically right” discount rate can be used both for the selection of projects and for deciding how much to save for the future, which in fact constitute one and the same set of decisions—selecting the projects includes choosing the total amount that is invested. One will first choose the highest-NPV investment plans (which are those with the highest rate of return for their particular time profile) and go

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36 Posner and Weisbach, Climate Change Justice at 161 (cited in note 1).
37 See Section V.
38 Posner and Weisbach, Climate Change Justice at 168 (cited in note 1).
on approving investments as long as the NPV of the remaining projects is positive. Note that the discount rate itself goes up in the process, because as more is invested for the future, future generations grow better off, which tends to raise the discount rate. Therefore a low discount rate advocated now, against the background of a business-as-usual scenario in which the future generations are in jeopardy, need not be the indication of the market rate that will prevail after the recommended investment has been made. The convergence value of the market rate will be somewhere between the initial market rate and the relatively lower initial discount rate.

Finally, let us briefly consider another objection raised by Posner and Weisbach against the ethicists. They claim that choosing projects as the ethicists propose may be futile when private decisions to consume rather than save may partly undo the public investments. Again, the ethicists can only agree and proclaim their innocence. Their criteria are meant to bear on final consequences, not on mistaken estimates of the consequences. If public investment exactly crowds out private investment, so that the government cannot influence the macroeconomic savings rate, there is no point for the government to try to change it and no point in applying any discount rate to this kind of decision. If, in a less extreme case, public savings only partly crowd out private savings, this must be taken into account, too, for an accurate description of the consequences of the policy.

IV. DISCOUNTING UNDER RISK

Having rebutted the main objections to the social welfare approach introduced in Section II, we now proceed to apply this methodology to climate policies. The basic methodology described in Section II ignores the important fact that the future is risky. This is especially relevant for the long run horizons of climate policies. Thus, we now extend the model, beginning by characterizing two different sorts of risk. First, the future growth of consumption is not known with certainty. Second, the effect of policies in the future is itself uncertain in general.

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39 This directly follows from the Ramsey formula introduced in Section II.
40 That is, a scenario in which there are no investments in mitigation or adaptation policies.
42 Both forms of uncertainty can be due to either random elements in otherwise well-understood mechanisms, or to epistemic uncertainty due to a lack of consensus about the mechanisms.
A. Considering Future Growth

Weitzman has proposed an interesting argument in favor of adopting even lower discount rates for investments that pay in the very long run when there is a background risk concerning the growth rate.\footnote{Weitzman, 36 J Envir Econ & Mgmt at 204-05 (cited in note 3).} Weitzman's argument is not based on the social welfare approach, but, in a similar fashion as Gollier,\footnote{Gollier, 85 J Pub Econ at 160-61 (cited in note 4).} we present a variant of Weitzman's model that enables us to connect his argument to Ramsey's formula.\footnote{See Equation (7) in Section II.} We later discuss Weitzman’s formulation, which has been retained by Posner and Weisbach.\footnote{Posner and Weisbach, Climate Change Justice at 152 (cited in note 1).}

Suppose that there is uncertainty about future consumption, and that our criterion is the expected value of social welfare (which is also, in the case of utilitarianism, the sum of expected utilities).\footnote{The criterion guiding the policy evaluation is some measure of social welfare—say, the sum over the whole population of expected utilities, or the utility of the least-well-off member of the population. Thus, as used in this article, “criterion” generally refers to any particular model (or equation) defining a measure of social welfare. See generally Amartya Sen, Choice, Welfare, and Measurement (MIT 1982). See also note 14.} Let us again consider two small changes, \( \Delta c_i \) and \( \Delta c_j \). Unlike the level of consumption, these changes are certain. The change in social welfare, from Equation (3), is now equal to

\[
-U'(c_i)\Delta c_i + E[U'(c_j)\Delta c_j],
\]

where \( E[\cdot] \) denotes the expected value, and the formula for the discount rate from Equation (5) becomes

\[
1 + \delta^* = \left( \frac{E[U'(c_j)]}{U'(c_i)} \right)^{-1/t}.
\]

(In our model with uncertainty, \( \delta^* \) now denotes the discount rate, and we keep the notation \( \delta \) for the discount rate in a particular state of the world.) What Weitzman noticed is that this kind of formula involves neither the expected value of \( 1 + \delta \), nor the expected value of \( (1 + \delta)^t \), but the expected value of \( (1 + \delta)^{-t} \). More precisely, recalling from Equation (5) in the previous section that in every particular state of the world, \( U'(c_j)/U'(c_i) = (1 + \delta)^{-t} \), Equation (9) becomes
\[ 1 + \delta^* = (E[(1 + \delta)^{-t}])^{-1/t}. \]  

Now, what is remarkable about this expression is that it has the form of a well-known quasi-arithmetic mean of the form, \((E[x^{-t}])^{-1/t}\), which is known to converge to the minimum value of \(x\) when \(t\) tends to infinity. Therefore, in the very long run, the discount rate under risk converges to the lowest possible value of the risk-free discount rate.\(^{48}\) This is a remarkable result. It implies that for long-term evaluations, one can focus on the worst-case scenarios in which future consumption is the lowest and the corresponding discount rate is the lowest.

To illustrate this result, consider the situation in which there is an 80 percent chance that the growth rate will be 1.3 percent on average in the future, but there is a 20 percent chance that it will be zero. Let us retain \(\rho = 2\), so that by applying Equation (7), we find that the risk-free discount rate is either 2.6 percent or 0 percent. This example, illustrated in Table 3, shows that while convergence to the lowest value (0 percent) may be rather slow, the discount rate is very quickly well below the probability-weighted average discount rate of \(0.8 \times 2.6 = 2.08\) percent.

<table>
<thead>
<tr>
<th>Table 3. The Discount Rate over Time with Uncertain Growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time horizon (years)</td>
</tr>
<tr>
<td>---------------------</td>
</tr>
<tr>
<td>50</td>
</tr>
<tr>
<td>100</td>
</tr>
<tr>
<td>200</td>
</tr>
<tr>
<td>500</td>
</tr>
<tr>
<td>1000</td>
</tr>
</tbody>
</table>

Note: There is an 80 percent chance that the growth rate will be 1.3 percent and a 20 percent chance it will be 0 percent.

Posner and Weisbach propose an intuitive explanation of this result directly based on Weitzman's original formulation.\(^{49}\) For every possible value of \(c_j\) there is a corresponding discount rate \(\delta\), in other words, a discount rate that would prevail if this particular scenario were bound to occur (which Weitzman

\(^{48}\) Weitzman, 36 J Envir Econ & Mgmt at 204-05 (cited in note 3).

\(^{49}\) Posner and Weisbach, *Climate Change Justice* at 152 (cited in note 1); Weitzman, 36 J Envir Econ & Mgmt at 205 (cited in note 3).
and Posner and Weisbach equate to the market rate, rather than the Ramsey\textsuperscript{50} rate.\textsuperscript{51} The expected value of the NPV of the investment, when all possible states of the world (more specifically, all possible discount rates) are considered, is then equal to

$$E \left[ -\Delta c_i + \frac{1}{(1+\delta)^t} \Delta c_j \right] = -\Delta c_i + E \left[ \frac{1}{(1+\delta)^t} \right] \Delta c_j.$$ \hfill (11)

By equating the right-hand side of Equation (11) to $-\Delta c_i + \frac{1}{(1+\delta)^t} \Delta c_j$, one directly obtains Formula (10).

This Weitzman-Posner-Weisbach derivation of the result remains, however, a little mysterious because it is not obvious why one should compute the expected present value of a project rather than some other formula. In fact, in general the expected present value is not the relevant figure. What should be computed, in the Ramsey approach, is the ratio of the expected values of the marginal utilities:

$$\frac{-\Delta c_i + E[U'(c_j)]}{E[U'(c_i)]} \Delta c_j,$$ \hfill (12)

but when there is no uncertainty about present consumption, the expected value of the marginal social value of $c_i$ is just the sure value $E[U'(c_i)] = U'(c_i)$, and therefore the ratio of expected values is, in this specific case of no uncertainty about the present, the expected value of the ratio.

B. Uncertainty about Returns to Investments

As mentioned earlier, risk typically affects not just the background growth rate of consumption but also the future yield of the investment. Taking account of this risk further complicates the discount rate. It is easy to show that the discount rate applied to expected benefits should be lower for projects with greater returns in states in which the marginal social utility of the beneficiaries is greater.\textsuperscript{52}

Because both growth and the benefits of climate policies are uncertain, we now evaluate whether Weitzman’s result of convergence to the lowest discount rate remains valid when the second layer of uncertainty is introduced. If risk

\textsuperscript{50} Recall from Equation (7) that the Ramsey discount rate is the product of the coefficient of inequality aversion and the annual growth rate of consumption.

\textsuperscript{51} Posner and Weisbach, \textit{Climate Change Justice} at 152 (cited in note 1); Weitzman, 36 J Envr Econ & Mgmt at 205 (cited in note 3).

\textsuperscript{52} See Gollier, 13 Chi J Intl L at 559 (cited in note 30).
takes the form of an uncertain rate of return on the investment, then, keeping the possible rates of return in the various states of the world fixed and varying the horizon, one obtains an interesting generalization of Weitzman’s result. In the long run, the discount rate that should be applied to the expected return of the investment tends to

$$\min \left( \frac{1 + \delta}{1 + r} \right) \max(1 + r) - 1,$$

(13)

where $\delta$ and $r$ are, respectively, the discount rate and the rate of return in various possible states of the world. When $r$ is not a random term, the expression in (13) simplifies to $\min(1 + \delta) - 1 = \min(\delta)$, that is, the lowest discount rate, as was explained previously. But when $r$ is random, other possibilities arise.

Let us first explain how to derive the result in (13). If one invests $1 in a project that has a random rate of return $r$ in $t$ periods, the marginal effect on expected social welfare is equal to

$$-U'(c_i) + E[U'(c_j)(1 + r)^t].$$

(14)

In present value, this reads

$$-1 + E \left[ \frac{U'(c_j)}{U'(c_i)} (1 + r)^t \right] = -1 + E \left[ \frac{1 + r}{1 + \delta} \right]^t.$$

(15)

In order to solve for $\delta^*$—the discount rate applied to the expected (uncertain) returns—now express the right-hand side Equation (15) in terms of $\delta^*$:

$$-1 + E \left[ \frac{1 + r}{1 + \delta} \right]^t = -1 + \frac{E[1 + r]^t}{(1 + \delta^*)^t}.$$  

(16)

From this equation one immediately derives

$$(1 + \delta^*)^t = \frac{E[1 + r]^t}{E \left[ \frac{1 + r}{1 + \delta} \right]^t}.$$  

(17)

Both in the numerator ($= E[1 + r]^t$) and in the denominator ($= E[(1 + r)/(1 + \delta)]^t$), the greatest term dominates when $t$ goes to infinity, which implies the generalized formula for $\delta^*$ in Equation (13).

---

\[^{53}\text{See text following Equation (10).}\]
The generalized formula (13) is particularly interesting when it is used to compare different kinds of investments. An investment that is most profitable in good times (such as, typically, a market investment) may have a low \((1 + \delta)/(1 + r)\) ratio in relatively good times when \(\delta\) is high, or in bad times when \(r\) is low. In both cases, the appropriate discount rate is greater than the lowest \(\delta\). In contrast, an investment that is most profitable in bad times (such as a climate policy that averts dangerous climate change) will definitely have to be evaluated with the lowest \(\delta\) because its greatest rate of return will happen in the states with the lowest discount rate. In conclusion, Weitzman’s argument that, in the long run, the discount rate converges to the lowest value may have to be watered down when applied to ordinary investments with returns that are correlated with growth, but seems to retain its full force for projects that are aimed at protecting us against climate hazards.

More recently, Weitzman\(^5\) proposed an even more striking, “dismal theorem” by arguing that the discount rate may come arbitrarily close to \(-100\) percent, even in a finite time horizon, implying that we should give absolute priority to the future.\(^5\) But this argument is much less convincing and a discussion of it can be found in a prior paper.\(^5\) We do agree with Weitzman, however, that a negative discount rate may be justified for climate policies, as discussed in Section VI.

V. PRIORITIZING THE POOR IN THE LONG RUN

We now develop a line of argument that incorporates not only intergenerational but also intragenerational inequality. This argument, in combination with the phenomenon described in the previous section of long-run convergence to the lowest discount rate, reinforces the presumption that negative values are relevant for evaluating climate policies.

Framing the discounting debate about the discount rate is somewhat misleading because there is not a single discount rate but rather as many discount rates as there are distributions of costs and benefits among different populations. We have already seen this phenomenon when the discount rate to be used depends on the time lag between generations, as in Table 3.

More generally, the formula that determines the discount rate is about changes in the consumption of two individuals, \(i\) and \(j\). The value of the

\(^5\) Id at 8.
discount rate depends on the consumption levels of these two individuals. Imagine now that two individuals from the same future generation, \( j \) and \( k \), not just one individual (\( j \) alone), will benefit from an increase in their consumption at the expense of one individual, \( i \), from the present generation. The formula for the change in social welfare, introduced in Equation (3), becomes

\[
-U'(c_i)\Delta c_i + U'(c_j)\Delta c_j + U'(c_k)\Delta c_k. \tag{18}
\]

As before, one can compute the present value by dividing by the marginal utility of \( c_i \), and then equate this with a formula using person-to-person discount rates \( \delta_{ij} \) and \( \delta_{ik} \):

\[
\Delta c_i + \frac{U'(c_j)}{U'(c_i)} \Delta c_j + \frac{U'(c_k)}{U'(c_i)} \Delta c_k \\
= -\Delta c_i + \frac{1}{(1 + \delta_{ij})^t} \Delta c_j + \frac{1}{(1 + \delta_{ik})^t} \Delta c_k. \tag{19}
\]

Now this formula is structurally similar to the formula obtained in the case of risk.\(^57\) Imagine that \( j \) and \( k \) share the benefit of the investment, \( B \), in fixed proportions: \( \Delta c_j = \alpha_j B \) and \( \Delta c_k = \alpha_k B \). The right-hand side of Equation (19) can then be written as

\[
-\Delta c_i + \frac{1}{(1 + \delta)^t} B, \tag{20}
\]

for

\[
\frac{1}{(1 + \delta)^t} = \alpha_j \frac{1}{(1 + \delta_{ij})^t} + \alpha_k \frac{1}{(1 + \delta_{ik})^t}. \tag{21}
\]

The same argument as in the previous section implies that in the very long run—in other words, when \( t \) tends to infinity—\( \delta \) will converge to the smallest value of person-to-person discount rates. The smallest value is obtained for the individuals who are the worst off in the future generation. Therefore, in the very long run, only the worst off members of future generations matter. (More precisely, one must focus on the worst off among those who benefit from the investment—those whose share is null play no role in the formula in Equation (21).)

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\(^{57}\) See Equation (10) in Section IV.
A complication is that the investment cost is generally paid by several members of the present generation. If one thinks of a public policy such as a mitigation effort in order to reduce greenhouse gas emissions, many individuals may be involved. Let us therefore consider the problem when two individuals \( i \) and \( I \) from the present generation contribute in fixed shares \( \alpha_i \) and \( \alpha_I \), so that \( \Delta c_i = \alpha_i D \) and \( \Delta c_I = \alpha_I D \). But to simplify the presentation, let us come back to the situation in which only one individual from a future generation, \( j \), stands to benefit from the investment. The formula for the change in social welfare becomes:

\[
-U'(c_i)\Delta c_i - U'(c_I)\Delta c_I + U'(c_j)\Delta c_I = -(U'(c_i)\alpha_i + U'(c_I)\alpha_I)D + U'(c_j)\Delta c_I. \tag{22}
\]

The present value can therefore be written as

\[
-D + \frac{U'(c_j)}{(U'(c_i)\alpha_i + U'(c_I)\alpha_I)}\Delta c_I = -D + \frac{1}{(1 + \delta)^t}\Delta c_I. \tag{23}
\]

for

\[
(1 + \delta)^t = \alpha_i(1 + \delta_{ij})^t + \alpha_I(1 + \delta_{ij})^t. \tag{24}
\]

This formula has the opposite behavior to the previous one: When \( t \) tends to infinity, \( \delta \) tends to the greatest value of the person-to-person discount rates. What is remarkable is that the greatest value is obtained for the worst off of the present generation, among those who share the cost.

When many individuals share the cost now and many individuals share the benefit in the future, these two results remain jointly valid, even though the formula is more complicated: In the very long run, the discount rate converges to the worst-off-to-worst-off discount rate, among the individuals who are affected by the change in consumption to be evaluated, that is, the discount rate applying to transfers from the worst off of the present generation to the worst off of the future generation. This result does not depend on the values of the shares, although, of course, the speed of convergence is influenced by the shares.

Table 4 illustrates this phenomenon with four individuals, two from each generation. Shares in cost and benefit are made to be equal (half-and-half) in

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58 See Fleurbaey and Zuber, *Ex Post Intergenerational Equity and Discounting* at *18 (cited in note 56) (providing a formal statement and a proof).

59 Id.
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Flurbary and Zuber

Every generation. In the present generation the poor consume one unit and the rich consume five units. The consumption of the poor incurs a growth of 1.3 percent per year, while the consumption of the rich has a growth rate of 1.5 percent. We keep $\rho = 2$.

**Table 4. Person-to-Person Discount Rates**

<table>
<thead>
<tr>
<th>Time horizon (years)</th>
<th>Society as a whole</th>
<th>Poor-Poor</th>
<th>Rich-Poor</th>
<th>Poor-Rich</th>
<th>Rich-Rich</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>2.63%</td>
<td>2.62%</td>
<td>-3.78%</td>
<td>9.87%</td>
<td>3.02%</td>
</tr>
<tr>
<td>100</td>
<td>2.63%</td>
<td>2.62%</td>
<td>-0.63%</td>
<td>6.39%</td>
<td>3.02%</td>
</tr>
<tr>
<td>200</td>
<td>2.63%</td>
<td>2.62%</td>
<td>0.98%</td>
<td>4.69%</td>
<td>3.02%</td>
</tr>
<tr>
<td>500</td>
<td>2.62%</td>
<td>2.62%</td>
<td>1.96%</td>
<td>3.69%</td>
<td>3.02%</td>
</tr>
<tr>
<td>1000</td>
<td>2.62%</td>
<td>2.62%</td>
<td>2.29%</td>
<td>3.35%</td>
<td>3.02%</td>
</tr>
</tbody>
</table>

The table shows that the poor-to-poor discount rate is a good indication of the social discount rate in this context, even at a moderate horizon (but this depends on the assumption about the shares of costs and benefits and is not always true). Observe that the rich-to-poor and the poor-to-rich discount rates change with the horizon because their relative consumption does not evolve according to a constant growth rate. In the beginning the poor subpopulation remains poorer than the rich of the first generation, which justifies a negative rich-to-poor discount rate, whereas the rich subpopulation is much richer than the poor of the first generation, which justifies a high poor-to-rich discount rate. In the long run, the relative consumption levels of beneficiary-donor correspond to average annual growth rates that converge to the growth rate of the receiving subpopulation, which explains the convergence of the specific person-to-person discount rates toward a discount rate that is specific to the beneficiary rather than specific to the donor. (In this particular setting with separate subpopulations with specific growth rates, the discount rate is also a weighted average of the two subpopulations' discount rates, and converges to the lowest discount rate—in other words, the discount rate of the subpopulation with the lowest growth rate, which ultimately becomes the poorer subpopulation even if it started out richer.)

**VI. Negative Discount Rates for Climate Policies**

We now come to the main thesis of this Article. Why should climate policies be evaluated with a negative discount rate? As we have just seen, the
person-to-person discount rate is negative when the present donor is richer than the future beneficiary. Thus, if we consider long-run policies, the discount rate should be negative when the poorest contributors to the policy are richer than the poorest beneficiaries. It is plausible that many climate policies satisfy this condition. Mitigation efforts, when they are well conceived, should put the financial burden on the high emitters, who are typically among the affluent members of the present generation, but such policies will benefit many members of future generations. Moreover, it is often said that the most vulnerable to climate change are the poorest, so that many of the future beneficiaries will be among the poorest of their generation. Can we hope that the poorest of future generations will be better off than the middle class of the present generation? Sadly, this appears unlikely. Therefore, climate policies that avoid imposing a burden on the poor members of the present generation deserve to be evaluated with a negative discount rate.

Another element reinforces this thesis. Weitzman’s result of a convergence toward the lowest discount rate in the case of risk combines with the result presented in this section. In the very long run, the discount rate converges to the worst-off-to-worst-off discount rate of the worst-case scenario. Therefore, even if there are favorable scenarios in which destitute populations catch up and reach good standards of living, it is enough to assign a positive probability to dark scenarios in which the standards of living of the poorest stagnate in order to validate our conclusion that negative discount rates are appropriate for evaluating climate (especially mitigation) policies.

Of course, this does not mean that such policies should have greater priority than other policies such as redistribution toward the poor members of the present generation. As we saw in Section II, choosing optimal policies requires not only checking that a chosen policy improves the status quo (that is, has a positive NPV), but also involves a comparison among positive NPVs. At a minimum, however, we want to argue strongly against the popular thesis that the market rate should be applied indiscriminately to the evaluation of all policies, independent of the affected populations.

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60 See, for example, World Bank, World Development Report 2010: Development and Climate Change (World Bank 2010).

61 As explained in the previous section (Section V), this is the discount rate to be used for transfers from the worst off of the present generation to the worst off of a future generation.

VII. BEYOND UTILITARIANISM

A. Inequality Aversion, Risk Aversion, and Correlated Climate Risks

So far we have adopted the utilitarian approach, which simply adds up individual utilities to evaluate social welfare.63 This approach predominates in the debate about discounting for the long run. The utilitarian approach is quite acceptable in the absence of risk, because the utility function can then be chosen, as suggested above, to embody the aversion to inequalities in consumption that the evaluator endorses.64 Under certain conditions, then, the utilitarian social welfare function can be applied by advocates of prioritarian and egalitarian theories of justice.65

In the presence of risk, things are harder. The coefficient of inequality aversion also becomes a coefficient of risk aversion if the utilitarian criterion is then applied as the sum of expected utilities (or equivalently, the expected sum of utilities). There is therefore a dilemma. One either respects the risk aversion of the population (assuming away a potential heterogeneity of risk preferences across individuals), which severely constrains the degree of inequality aversion, or one adopts a coefficient of inequality aversion on the basis of ethical principles but then potentially imposes on the population a high degree of risk aversion that appears paternalistic. This is a classical problem in social ethics—over fifty years ago, in fact, Harsanyi viewed it as a key justification of utilitarianism66—and it continues to be discussed in the context of discounting.67

63 See Equation (1) in Section II.
64 See text accompanying notes 14–18.
65 Formally, the utilitarian social welfare can also be adopted by prioritarians and egalitarians who accept the property of subgroup separability that underlies the additive form of the criterion. Subgroup separability means that the evaluation of a change affecting a subgroup of the population can ignore the consumption level of the unconcerned individuals and focus on the affected subgroup only. By an important theorem proved by Debreu and Gorman, subgroup separability implies that the evaluation criterion can be represented by an additive function. See Charles Blackorby, Daniel Primont, and R. Robert Russell, Duality, Separability, and Functional Structure: Theory and Economic Applications (North-Holland 1978); Gérard Debreu, Topological Methods in Cardinal Utility Theory, in Kenneth J. Arrow, Samuel Karlin, and Patrick Suppes, eds., Mathematical Methods in the Social Sciences, 1959: Proceedings of the First Stanford Symposium 16, 24 (Stanford 1960); William M. Gorman, The Structure of Utility Functions, 35 Rev Econ Studies 367, 381–83 (1968).
67 See, for example, Louis Kaplow and David Weisbach, Discount Rates, Social Judgments, Individuals’ Risk Preferences, and Uncertainty, 42 J Risk & Uncertainty 125, 140–41 (2011).
Fleurbaey has proposed a compromise, arguing that respecting preferences is much less compelling under uncertainty than in a risk-free context because in the context of risk, by definition, individuals are not perfectly informed about the consequences of their decisions. In particular, respecting preferences under risk may even appear to betray the individuals’ informed preferences when the evaluator has information about the final distribution of individual well-being. Suppose, for instance, that individuals are willing to take a risk, even though they know in advance that the only consequence of this risk is a widening of inequalities, without any overall gain. At the individual level the risk may appear attractive, but at the social level it is already known that many will be unlucky and that these individuals are actually acting against their true interests when they are willing to take such a risk. In other words, when making a decision under risk, each individual focuses on his own payoffs and ignores the correlation of his outcome with that of other individuals. A social evaluator can take account of this correlation and forecast how many individuals will turn out to have acted against their ultimate interests.

This observation leads to the conclusion that respecting risk preferences is not always necessary. But it also suggests that respecting risk preferences remains an attractive idea when there is perfect correlation between individuals, because in such a situation an evaluator cannot forecast whether some of them would be acting against their interests by accepting the risk. Fleurbaey shows that when the requirement to respect risk preferences is limited to the case of perfect correlation, criteria other than utilitarianism become acceptable, permitting a greater degree of inequality aversion. His Theorem 1 stipulates that, under minimal conditions of rationality under uncertainty, all such criteria must take the form of the expected value of the equally distributed equivalent (EDE) utility, which is the level of utility that would yield the same social welfare if it were equally distributed across all individuals.

Let us illustrate this with a particular functional form. Suppose that \( E[u(c)] \) represents the risk preferences of the individuals, assuming away any heterogeneity across individuals in order to keep things simple and in line with the literature on discounting. Suppose that in absence of risk one would like to use the prioritarian criterion \( \sum_i \phi(u(c_i)) \), where \( \phi \) is a concave function

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69 Id at 657. The notion of EDE is due to Anthony B. Atkinson, On the Measurement of Inequality, J Econ Theory 244, 250 (1970).
70 We now use the lower case to distinguish this utility function, which embodies risk attitudes, from the previous upper-case utility function, which embodied the ethical values of the evaluator about inequality.
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embodiing a priority for the worst off in utility. Then the expected EDE criterion takes the form

\[ E \left[ \varphi^{-1} \left( \frac{1}{n} \sum_i \varphi(u(c_i)) \right) \right], \]  

(25)

where \( \varphi^{-1}(\cdot) \) denotes the inverse function and \( n \) is the number of individuals.

In an earlier paper,\(^71\) we study how this kind of criterion can be used in the computation of the discount rate. What is important is that the discount rate can then be approximated by the usual Ramsey discount rate, obtained for the additive social welfare function \( \sum_i \varphi(u(c_i)) \),\(^72\) to which one has to add a term that depends (positively) on the correlation between the well-being of the beneficiaries of the investment and social welfare at the global level. (There is an additional term capturing the attitude toward population size reflected by the criterion—an issue that will be explained later.)

It is not easy to figure out whether this result pushes in the direction of raising or lowering the discount rate for climate policies. A primary issue is whether climate risks generate common risks for most populations or induce negative correlations. In the case of common risks, the correlation term is positive and tends to raise the discount rate. The case of negative correlations is possible if a change in the climate would actually be beneficial in the high latitudes where the most affluent populations are now settled, whereas it would be dramatic for the subtropical areas in which the most vulnerable populations live.

But even if negative correlations between subpopulations occur, it is still possible for the correlation term to be positive. Indeed, recall that in the long run, the poor members of the future generations are those who matter for the discount rate. If the degree of inequality aversion (in other words, the concavity of function \( \varphi(\cdot) \)) is strong, social welfare as measured by the EDE is then close in value to the lowest utility in society, and therefore directly correlated with the well-being of the worst off.

Not much is known about the size of the correlation term and simulations are not easy to perform because they require considering scenarios that describe the situation of the whole human species, from beginning to end. An example of simulations is provided in the Appendix and shows that the difference between criteria may be far from negligible.

\(^71\) Fleurbaey and Zuber, *Ex Post Intergenerational Equity and Discounting* at *22 (cited in note 56).

\(^72\) When applying Equation (1), however, one must of course replace the function \( U(c) \) that appears in Equation (5) by the composition function \( \varphi(u(c)) \).
B. The Risk of Extinction and Optimal Population Size

In the Stern Review there is a 0.1 percent additional term that comes from the estimated exogenous 1/1000 risk per annum of extinction of the species due to cosmic phenomena (meteors, eruptions) or unforeseen disruptions of life systems (pandemics).\(^3\) The underlying utilitarian reasoning is that the expected value of total utility is equal to

\[
U(c_0) + \frac{999}{1000} U(c_1) + \left(\frac{999}{1000}\right)^2 U(c_2) + \ldots. \tag{26}
\]

The computation of the discount rate then introduces an additional factor, \(\left(\frac{999}{1000}\right)^t\), into the formula of the marginal change in social welfare:

\[
-U'(c_i)\Delta c_i + \left(\frac{999}{1000}\right)^t U'(c_j)\Delta c_j, \tag{27}
\]

implying

\[
1 + \delta = \frac{1000}{999} \left(\frac{U'(c_i)}{U'(c_j)}\right)^{-1/t}, \tag{28}
\]

which is approximately equivalent to adding 0.001 to the initial value of \(\delta\).

Incorporating this factor introduces an additional issue. Different values for the longevity of the human species imply different sizes for the total human population, which requires taking a stance on the question of the optimal size of the population. In the utilitarian galaxy, there are three popular approaches to integrating population preference into the social welfare criterion.\(^4\) Total utilitarianism, implicitly adopted above, adds utilities considering that a new member with a positive utility always improves social welfare.\(^5\) Critical-level utilitarianism (favored by Blackorby and his co-authors) similarly adds utilities but deducts a fixed amount for every new member.\(^6\) In other words, it computes the sum of \(U(c_i) - \gamma\), which means that adding a new member to society is considered beneficial only if his utility is above \(\gamma\). The introduction of the critical level, however, does not affect the marginal utility of consumption for existing

\(^3\) In other words, extinction not caused by climate change. Stern, The Stern Review at 184 (cited in note 5).


\(^5\) Id at 136.

\(^6\) Id at 137.
members and therefore does not affect the discount rate. The third approach is 
average utilitarianism, which divides total utility by the size of the population and 
considers that adding new members is desirable only when their utility is above 
average.77 The computation of the discount rate for this third approach is 
substantially different and, to the best of our knowledge, has not been explored.

It is also possible to introduce additional parameters in Equation (25) to 
express various attitudes to population size in the EDE criterion. But unlike 
critical-level utilitarianism, there is only one constant critical level that can be 
taken, and this is the lowest possible utility. Another salient option—which 
consists in keeping Equation (25) unchanged and applying it to the comparison 
of populations of different sizes—implies an implicit critical level that is equal to 
the EDE itself. That is, adding an individual whose well-being is above the EDE 
level of the initial population raises the value of the EDE. For a significant 
degree of inequality aversion, the EDE is close to the lowest utility in the 
population, which may not be an unreasonable option for the critical level. 
Depending on which of these two options is chosen, the discount rate will 
contain an additional term that is either negatively or positively related to the 
correlation between the well-being of the beneficiaries of the investment and the 
population size.78

In conclusion, the appropriate introduction of aversion to inequality in the 
presence of risk as well as suitable ethical attitudes about the desirable size of the 
population may complicate the computation of the discount rate. As the 
discount rate encapsulates the social welfare perspective on transfers across 
generations, it is not surprising that these considerations cannot be ignored in its 
computation. Though these issues complicate the analysis, it is at least 
comforting that it is possible to make the link between ethical principles and the 
value obtained for the discount rate explicit and transparent.

VIII. CONCLUSION

Posner and Weisbach advocate selecting projects with a discount rate equal 
to the market rate on the basis of concerns for efficiency and opportunity costs. 
However, they accept the idea that ethical principles may play a role in 
determining how much in total should be invested for the future. We have 
argued here that the social welfare methodology, which derives the discount rate 
from the social welfare tradeoffs between individuals belonging to different 
generations, takes care of such concerns appropriately and captures the relevant

77 Id at 143.
78 For further details, see Fleurbaey and Zuber, Ex Post Intergenerational Equity and Discounting (cited in 
note 56).

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ethical issues not just for the selection of projects but also for deciding how much we should invest overall.

In a nutshell, the discount rate need only serve to measure the relative social priority of different individuals belonging to different generations. Therefore there is no need to worry about comparing the discount rate to the market interest rate, because a rational evaluation in terms of present value at the chosen discount rate will never fail to avoid dominated investments, and never fail to choose those with the greatest rate of return. The key message of this Article is that discount rates are really to be computed between individuals (person-to-person), which gives a great role to inequalities within and between generations. Therefore, in the very long run, Weitzman’s observation that the worst-case scenario drives the discount rate has to be supplemented by the conclusion that the discount rate is also driven by the welfare of the individuals who are worst off when the investment is paid for and when its benefits are felt.

Therefore, if climate policies such as mitigation efforts are paid for by the affluent populations of present generations and greatly benefit the worst off of distant future generations in the most catastrophic scenarios, it is very likely that the correct discount rates for the evaluation of such policies are negative, which means that a dollar of benefit in the distant future is worth more than a dollar of effort today.

In conclusion, we would like to recall that a rigorous evaluation of climate policies is particularly challenging because it requires rethinking the welfare economics of risk, time, and population. In such an endeavor the utilitarian criterion, which remains prominent in the debates about discounting, should be questioned and, perhaps, replaced with other criteria that better combine a certain respect for the risk preferences of the population and a substantial degree of aversion to inequality.

Finally, we should recall a point that has already been made by Stern: The discount rate is useful to evaluate small transfers of consumption across individuals living at different times. It is not an all-purpose tool that can serve for all evaluations. It is not adapted to large-scale changes, and it is also not adapted to evaluating policies that change the size of the population or the probabilities of different scenarios. For such policies one has to go back to the underlying social welfare criteria. This is an additional reason to pay careful attention to the selection of such criteria on sound ethical principles.

APPENDIX

In this appendix, we provide a simple illustration of the discount rate obtained by the various utilitarian criteria and by the EDE in a simple two-state scenario. We assume that in the favorable state the human species spans two million years, comprising eighty thousand generations (a generation is assumed to span twenty-five years), and we assume that four thousand generations (one hundred thousand years) have already lived up to now. The world population is assumed to be stable from now on, with three billion members per generation (three generations overlap at any given moment in time). The past population since year zero is assumed to have grown from an initial number of two individuals at a rate of 0.3 percent per generation until ten thousand years ago (year 90,000), with the growth rate then rising to 2.62 percent per generation.

There are two dynasties, one consuming one unit today and the other consuming five units today. The evolution of consumption over time can hardly be assumed to be exponential over such a long horizon. Indeed, assuming that the first generation consumed 0.04 units per capita, the growth rate of per capita consumption up to now would have been 0.081 percent on average per generation. This rate seems very small, but would imply that the last generation in 1.9 million years would consume about $10^{26}$ times as much as people now, a number that is probably much greater than the number of planets in the universe.

We will instead assume that consumption is constant, except for the period 1760–2260, in which the growth rate per year is approximately 1.3 percent and consumption grows by a factor of 625. Inequality remains constant between the two dynasties. After the growth transition, future generations consume twenty-five times our current consumption level.

In order to introduce risk we also assume that with a 20 percent probability, consumption will stagnate permanently from now on, and that only forty thousand generations live (extinction after one million years). This is the unfavorable state.

We retain the utility function of the following form

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80 See text accompanying notes 74–77.
81 See text accompanying note 69.
82 If 1 unit is worth $10,000 per annum, 0.04 units is slightly above $1 per day.
84 See Equation (2) in Section II.
and let

$$u(c) = \frac{1}{1 - \rho} (c^{1 - \rho} - \hat{c}^{1 - \rho}), \quad (A1)$$

with $\rho = \varepsilon = 2$ and $\hat{c} = 0.02$ ($0.02$ being half of the first generation's consumption). We consider a policy that is paid for only by the rich dynasty of the 4,000th generation (the present generation) and benefits every dynasty in future generations equally. That is, we ask how much a $1$ benefit equally shared between rich and poor in the future is worth, compared to $1$ paid by the rich today.

<table>
<thead>
<tr>
<th>Time horizon (years)</th>
<th>EDE (equally distributed equivalent)</th>
<th>Total or critical-level utilitarian</th>
<th>Average utilitarian</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>-3.81%</td>
<td>-3.34%</td>
<td>-3.77%</td>
</tr>
<tr>
<td>100</td>
<td>-1.64%</td>
<td>-1.21%</td>
<td>-1.62%</td>
</tr>
<tr>
<td>200</td>
<td>-0.76%</td>
<td>-0.49%</td>
<td>-0.75%</td>
</tr>
<tr>
<td>500</td>
<td>-0.30%</td>
<td>-0.19%</td>
<td>-0.30%</td>
</tr>
<tr>
<td>1000</td>
<td>-0.15%</td>
<td>-0.10%</td>
<td>-0.15%</td>
</tr>
</tbody>
</table>

The main lesson of Table A1 is that the difference between the criteria is far from negligible. It appears that the difference between the EDE and average utilitarian criteria is smaller than the difference between these two criteria and total utilitarianism. However, other simulations done by the authors for different consumption paths show that other patterns are also possible. The fact that the discount rates are not very different between the utilitarian criteria and the EDE (which introduces additional inequality aversion via the function $\phi(.)$) is a direct consequence of adopting a utility function that varies very little between the consumptions of one to five units, so that the social priority between the rich and poor dynasties is mostly determined by marginal utility, as in utilitarianism.

The discount rates in Table A1 tend to zero in the very long run because the difference in consumption between the donors (five units) and the worst off in the worst scenario (one unit) becomes very small in terms of annual growth rate. Observe that a discount rate of -3 percent per annum places a strong
priority on the future: it means that it is worth sacrificing $4.60 now to transfer $1 fifty years into the future.