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The text

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Abstract

We defend a methodology of discounting, for the evaluation of the long-term effects of climate policies, which relies on a social welfare objective, against the view that the market rate of return should be used for that purpose. We also show that in the long run, the discount rate for such policies should focus on the worst-case scenario for the most disadvantaged populations. As a consequence, it is likely that the appropriate discount rate for climate policies should be negative, implying a high priority for the future.

Keywords

discounting, climate policy, intergenerational equity

Un taux d'escompte négatif pour les politiques climatiques

Résumé

Nous défendons une méthodologie de l'actualisation, pour l'évaluation des effets à long terme des politiques climatiques, qui repose sur un objectif de bien-être social, contre l'idée que le taux de rendement du marché doit être utilisé à cette fin. Nous montrons aussi que dans le long terme, le taux d'actualisation pour de telles politiques devrait se concentrer sur le scénario le plus défavorable pour les populations les plus défavorisées. En conséquence, il est probable que le taux d'actualisation approprié pour les politiques climatiques doive être négatif, ce qui implique une grande priorité pour le futur.

Mots-clés

taux d'escompte, politique climatique, équité intergénérationnelle

Sommaire

Since the Stern Review (Stern 2007) and the debate it has sparked off, the discount rate has been at the center of heated discussions about climate policies. In the very long run, the discount rate makes a huge difference in the evaluation of policies. The following table (Table 1) shows the minimum return that a $1 investment for the future should have to be considered better than consuming it now, depending on the discount rate that is adopted and depending on the horizon. The 1.4% discount rate is advocated by the Stern Review, but later Stern suggested that 2.7% might be a better figure. The table shows that this hesitation is not innocuous. Obviously, adopting a much higher discount rate as recommended by Nordhaus (2007) –around 5.5% – has even more extreme consequences.

Table 1: The implications of different discount rates

Horizon	1.4%	2.7%	Ratio
50	2.00	3.79	1.89
100	4.02	14.36	3.57
200	16.13	206.11	12.78
500	1,044	609,848	584
1000	1,091,327	371,914,916,666	340,791

Legend: With a 1.40% discount rate, a $1 investment today must yield at least $4.02 in 100 years; with a 2.70% discount rate, the number jumps to $14.36, which is 3.57 greater.

The thesis defended in this paper is that climate policies may justify the use of a negative discount rate for their evaluation. There are two important steps in the argument, each of which is an interesting separate thesis: 1) Different policies should be evaluated with different discount rates depending on what populations are impacted; 2) In the long run only the worst scenario for the worst-off fraction of the population counts.

Our thesis is at odds with the conclusion of Chapter 7 in Posner and Weisbach (2010 –hereafter PW), even though we share the same premises: impartiality between generations, compatibility with ethical principles, and taking opportunity costs into account. They 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. The main difference is that we disagree 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 PW, it serves to take into account the opportunity cost of the investment.

Our thesis is somewhat closer to Weitzman's and Gollier's arguments in favor of using a small, possibly a negative discount rate (Weitzman 1998, Gollier 2002), but involves different reasons. The paper is structured as follows. In the next section we briefly review the arguments of the advocates of the descriptive and the prescriptive approaches, in the debate about discounting (the "ethicists" and the "positivists", as called by PW), and discuss agreements and disagreements with PW. Then in the next two sections we explain the methodology of computation of the discount and propose a reformulation of the Weitzman-Gollier set of arguments to the context of risk. The following section explains our core arguments. For the sake of an easy presentation, the bulk of the paper is formulated in the context of utilitarian reasoning, but we explain in the penultimate section why the utilitarian approach must be replaced with a more promising approach and how this can affect the discount rate. The final section concludes.

The descriptive-prescriptive debate

The opposition between a descriptive approach and the prescriptive approach is hard to understand when it is labeled in this way, as suggested by Arrow et al. (1996). It is equally puzzling when the "ethicists"-"positivists" labels are used. As PW write, "in the end, of course, the positivists' approach is worth nothing unless it can be defended on ethical grounds." (p. 150) So, the debate is not between ethics and something else, it is a debate *within* ethics.

The descriptive approach invokes 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 (Nordhaus 2007). 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. The first is to seek to impose the population preferences on every evaluator. Obviously, there are many views in 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 shared this concern, the evaluator might be right against everyone else. Just as there is freedom of thought, just as different political parties can have their own platforms, there should be a space for economic evaluation that embodies various views about social welfare and the principles of intergenerational equity.

The reply to this objection will certainly be: Any evaluation is admissible, 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 policies against the majority opinion (e.g., the abolition of death penalty in France in 1981). But this powerful 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 ponder 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 preferences over intertemporal trade-offs. The market interest rates are determined by the joint effect of technical possibilities (the productivity of capital) and the willingness of investors to transfer wealth into the future, with a benefit. 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 the investors' and savers' common marginal rate of substitution across time. This is true but investors and savers make decisions to transfer wealth for themselves by 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 don't ask them this outlandish question, and therefore we cannot pretend to use their answer to a different question 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 NGOs focused on the climate might be the relevant source of information), it is doubtful that such preferences would be more respectable than the outcome of an outright democratic debate involving 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 guarantee that they will be adopted).

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, in PW. It is this argument that leads PW to propose using the market interest rate. 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% or lower. The objection is that investing the same amount at the market rate, which is supposedly greater, would bring greater benefits to the future. Using a lower discount rate than the market is therefore branded as a recipe for choosing dominated policies which 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 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 may induce inefficient (i.e., dominated at each period) choices. It will only imply making different choices among the efficient (i.e., 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 high rate of return is possible. If a business-as-usual investment policy that puts all savings in the financial market brings more benefits to the future generations than a mitigation policy aimed at curbing GHG emissions, even the most devoted disciple of the Stern Review will approve it.

To illustrate this point, Table 2 presents an example of four policies, with their undiscounted benefits and their NPV according to two different values of the discount rate (1.4% is from the Stern Review, 5.5% has been advocated by Nordhaus). Policies A and C are market investments at 5.5%, policy B is a climate policy with impacts equivalent to a 10% monetary return, policy D is a climate policy with impacts equivalent to a 6% return. Policies A and B yield returns in 100 years, while policies C and D pay in 500 years. The 5.5% discount rate enables us to check that climate policies B and D are not dominated by market investments, but is it helpful to choose between B and D? It suggests that B, which has impacts of greater value in the shorter term, is preferable to D. But a lower discount rate at 1.4% suggests otherwise, while still revealing that these climate policies are not dominated by the market. It is therefore important to have a good discount rate, not 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.

In conclusion to this point, when PW 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 deserving different discount rates, which is equivalent to incorporating social benefits in the computation of their rate of return.)

There is another related methodological issue on which we disagree with PW. They propose to use 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.” (p. 168) This separation

Table 2: How to choose policies with various discount rates

Horizon	A	B	C	D
0	-1	-1	-1	-1
100	211	13781	0	0
500	0	0	4,23E+11	4,50E+12
Present value				
1,40%	51,66	3430,41	4,05E+08	4,30E+09
5,50%	0,00	64,17	0,00	9,63

Legend: Policy A costs $1 today and pays $211 in 100 years; at a 1.4% discount rate, the present value is $51.66; at a 5.5% discount rate, it is $0.

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 to decide how much to save for the benefit of the future generations. In other words, two discount rates would be used in the methodology proposed by PW, although they do not make it fully explicit (and would perhaps allow for other considerations 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, whereas the choice of particular projects would use the market rate in order to make sure to pick 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 when to stop saving for the future, which constitute in fact one and the same set of decisions –selecting the projects includes choosing the amount that is invested. One will start with the highest-NPV investment plans (which are those with the highest rate of return for their particular time profile) and go on 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, the future generations grow better off, which tends to raise the discount rate (see below for an explanation of this phenomenon). Therefore a low discount rate advocated now, on 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 done. The convergence value of the market rate will be somewhere between the initial market rate and the initial discount rate.

Finally, let us briefly consider another objection raised by PW against the ethicists. They claim that choosing projects as the ethicists propose may be futile when private decisions to dissave 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 a certain Ricardian equivalence implies 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 partly crowd out private savings, this must be taken into account, too.

In this section we have defended the ethicists and their prescriptive approach against the attacks of the positivists with their descriptive approach, but we haven't said a word, almost, about what the prescriptive approach says and how it computes its discount rate. To this we now turn.

The methodology of discounting

As announced in the introduction, for simplicity we will provisionally adopt the utilitarian way of defining social welfare, and more precisely assume that social welfare can be computed as the sum of $U(c_i)$, where c_i is the consumption level of individual i. What is important about this approach is that the function U is assumed to be the same for all individuals, which means in particular that there is no preference for earlier generations against future generations, and we consider that this function embodies the preferences of the evaluator about inequalities in consumption –which means that, in terms of consumption, the approach is prioritarian rather than utilitarian. We will even adopt an assumption that is common in the economic literature, and gives a special form to the utility function:

$$U(c) = \frac{1}{1-\rho}\left(c^{1-\rho} - \hat{c}^{1-\rho}\right),$$

where ρ can be interpreted as a coefficient of aversion for consumption inequality, and $\hat{c}$ is the minimum level of consumption that is required to make utility positive. With this function, the marginal utility is equal to $c^{-\rho}$, which makes things 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 paper.

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 Δc_j. Is this good for social welfare? If the changes are infinitesimal, one can use the marginal utilities to evaluate the changes, and the variation in social welfare is then equal to

$$-U'(c_i)\Delta c_i + U'(c_j)\Delta c_j.$$

This can be expressed in present value by dividing every term by the marginal utility of c_i,

$$-\Delta c_i + \frac{U'(c_j)}{U'(c_i)}\Delta c_j,$$

and by comparing this expression with the discounted sum $-\Delta c_i + \frac{1}{(1+\delta)^t}\Delta c_j$, one obtains the discount rate by the formula

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

The discount rate is a direct expression of the relative priority of the two individuals (or generations), modulated by the time distance between the two individuals. If the future individual is better off than the present individual, the expression is greater than one, i.e., the discount rate is positive.

This methodology gives the 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. 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 into

$$1+\delta = \left(1+g_{ij}\right)^{\rho},$$

where $g_{ij} = \left(\frac{c_j}{c_i}\right)^{1/t} - 1$ is the annual growth rate of consumption between c_i and c_j. When g_{ij} is small, this formula can be approximated by the famous Ramsey formula $\delta = \rho g_{ij}$.

A reasonable value for inequality aversion is $\rho = 2$ (the Stern Review took $\rho = 1$) while a standard estimate for the growth rate is 1.3 (as in the Stern Review), which implies a discount rate of approximately 2.6% (Stern adds a 0.1% term due to the risk of extinction of humanity, we ignore this term for the moment). This discount rate may be much lower than the market rate of return, but, as explained in the previous section, this is not particularly threatening for this methodology and there is no danger of choosing dominated investment plans.

Discounting under risk

Weitzman (1998) 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 on the growth rate. We first present a variant of it which enables us to connect the argument to Ramsey's formula, in a similar fashion as in Gollier (2002). 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). Let us again consider two small changes Δc_i and Δc_j. Unlike the level of consumption, these changes are certain. The change in social welfare is now equal to

$$-U'(c_i)\Delta c_i + EU'(c_j)\Delta c_j,$$

where E denotes the expected value, and the formula for the discount rate becomes:

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

(δ^* now denotes the discount rate, and we keep the notation δ for the discount rate in a particular state of nature.) 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 the previous section that in every particular state of the world, $U'(c_j)/U'(c_i) = (1+\delta)^{-t}$, one has

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

Now, what is remarkable about this expression is that it has the form of a well-known quasi-arithmetic mean of the form $\left(E\left[x^{-t}\right]\right)^{-1/t}$, 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. This is a remarkable result. For long term evaluations, one can focus on the worst scenarios in which future consumption is the lowest and the corresponding discount rate is the lowest.

PW propose an intuitive explanation of this reasoning directly based on Weitzman's original formulation. For every possible value of c_j there is a corresponding discount rate δ (which Weitzman and PW assimilate to the market rate, rather than the Ramsey rate, in the corresponding scenario). The expected present value of the investment, when all possible discount rates are considered, is then equal to

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

and by comparing this expression to $-\Delta c_i + \frac{1}{(1+\delta^*)^t}\Delta c_j$, one directly obtains the desired formula.

This explanation 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 correct. What should be computed, in the Ramsey approach, is the ratio of the expected values of the marginal utilities,

$$\Delta c_i + \frac{EU'(c_j)}{EU'(c_i)}\Delta c_j,$$

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

To illustrate the result, consider the situation in which with 80% chance, the growth rate will be 1.3% on average in the future, but there is 20% chance that it will be zero. Let us retain $\rho = 2$, so that the risk-free discount rate is either 2.6% or 0%. This example shows that the convergence to the lowest value may be rather slow, but also that the discount rate is very quickly well below the average discount rate 0.8x2.6 = 2.08%.

Table 3: Discount rate for different horizons when the growth rate is either 1.3% or 0%

Horizon	Discount rate
50	1,74%
100	1,35%
200	0,80%
500	0,32%
1000	0,16%

Admittedly, 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, and 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.

For our discussion of climate policy, it is especially relevant to see if the Weitzman convergence to the lowest discount rate remains valid in this context. If risk takes the form of an uncertain rate of return on the investment, then, keeping the possible rates of return in the various states of nature 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

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

where δ and r are, respectively, the discount rate and the rate of return in the various possible states of the world. When r is not a random term, this expression singles out the lowest discount rate, as was explained previously. But when r is random, other possibilities appear.

Let us first explain how to derive this result. 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

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

In present value, this reads

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

Now, suppose one wants to equate this to a NPV with a discount rate applied to expected returns:

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

From this equation one immediately derives

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

At the numerator as well as at the denominator, the greatest term dominates when t goes to infinity, which implies the generalized formula.

This generalized formula 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 in which δ is high, or in bad times in which r is low. In both cases, the appropriate discount rate is greater than the lowest δ. 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 δ because its greatest rate of return will happen in the states with the lowest discount rate. In conclusion, Weitzman's argument 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.

Weitzman (2009) proposed an even more striking ("dismal") thesis by arguing that the discount rate can be made arbitrarily close to -100% even in the short run. But this argument is much less convincing and a discussion of it can be found in Fleurbaey and Zuber (2012).

Priority for the poor in the long run

We do agree with Weitzman, however, that a negative discount rate may be justified for climate policies. There is another line of argument that, combined with the phenomenon, described in the previous section, of convergence toward to the lowest rate in the long run, reinforces the presumption that negative values are relevant.

The debate about "the" discount rate is somewhat misleading because there is not *a* single discount rate but 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, j. The value of the discount rate depends on the consumption levels of these two individuals. Imagine now that two individuals j, k from a future generation, not just one individual, will benefit from a change in their consumption, so that we have to deal with the formula

$$-U'(c_i)\Delta c_i + U'(c_j)\Delta c_j + U'(c_k)\Delta c_k.$$

As before, one can compute the present value by dividing by the marginal utility of c_i, and compare this with a formula involving person-to-person discount rates:

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

Now this formula is structurally similar to the formula obtained in the case of risk. Imagine that j and k share the benefit of the investment in fixed proportions: $\Delta c_j = \alpha_j B$ and $\Delta c_k = \alpha_k B$. The above expression can then be written as

$$-\Delta c_i + \frac{1}{(1+\delta)^t} B,$$

for

$$\frac{1}{(1+\delta)^t} = \alpha_j \frac{1}{(1+\delta_{ij})^t} + \alpha_k \frac{1}{(1+\delta_{ik})^t}.$$

The same argument as in the previous section implies that in the very long run, i.e., when t tends to infinity, δ 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 of the 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.

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 to reduce GHG emissions, many individuals may be involved. Let us therefore consider the problem when several people from the present generation contribute in fixed shares: $\Delta c_i = \alpha_i C$ and $\Delta c_l = \alpha_l C$. But to simplify the presentation, let us come back to a situation in which only one individual from a future generation stands to benefit from the investment. The formula is now the following:

$$-U'(c_i)\Delta c_i - U'(c_l)\Delta c_l + U'(c_j)\Delta c_j = -(U'(c_i)\alpha_i + U'(c_l)\alpha_l)C + U'(c_j)\Delta c_j.$$

The present value can therefore be written as

$$-C + \frac{U'(c_j)}{(U'(c_i)\alpha_i + U'(c_l)\alpha_l)}\Delta c_j = -C + \frac{1}{(1+\delta)^t}\Delta c_j$$

for

$$(1+\delta)^t = \alpha_i\left(1+\delta_{ij}\right)^t + \alpha_l\left(1+\delta_{lj}\right)^t.$$

This formula has the opposite behavior to the previous one. When t tends to infinity, δ 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 in 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 (for a formal statement and a proof, see Fleurbaey and Zuber 2012). This holds whatever 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 supposed to be equal (half-half) in every generation. In the present generation the poor has a consumption of 1 unit, the rich has a consumption of 5 units. The dynasty of the poor has a consumption growing at 1.3% per year, the dynasty of the rich enjoys a growth rate of 1.5%. We keep $\rho = 2$.

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 shares and is not true in general). 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 dynasty remains poorer than the rich of the first generation, which justifies a negative rich-to-poor discount rate, whereas the rich dynasty 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 consumptions tend to follow the growth rate of each dynasty, which explains the convergence toward a discount rate that is specific to the beneficiary rather than specific to the donor. (In this particular setting with separate dynasties with specific growth rates, the discount rate is also a weighted average of the two dynasties' discount rates, and converges to the lowest discount rate, i.e., the discount rate of the dynasty with the lowest growth rate, which ultimately becomes the poorer dynasty even if it starts richer.)

We now come to the main thesis of this paper. Why should climate policies be evaluated with a negative discount rate? The person-to-person discount rate is negative when the present donor is richer than the future beneficiary. Given the above result, 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 burden on the high emitters who are typically among the affluent members of the present generation, but they 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 beneficiaries in the future 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? This appears, sadly, 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.

Table 4: The discount rate at different horizons, for society as a whole (column 2) and the person-to-person discount rates (columns 3-6)

Horizon	Discount rate	Poor-Poor	Rich-Poor	Poor-Rich	Rich-Rich
50	2,63%	2,62%	-3,78%	9,87%	3,02%
100	2,63%	2,62%	-0,63%	6,39%	3,02%
200	2,63%	2,62%	0,98%	4,69%	3,02%
500	2,62%	2,62%	1,96%	3,69%	3,02%
1000	2,62%	2,62%	2,29%	3,35%	3,02%

Another element reinforces the 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 the 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 about the negative discount rate for 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 (Schelling 1995). The choice of the best policies, as we have seen in the second section, involves a comparison of present values, not just checking that the chosen policy improves on the status quo. At least, however, we want to argue strongly against the popular thesis that the market rate should be applied indiscriminately to the evaluation of all policies, independently of the affected populations.

Beyond utilitarianism

So far we have adopted the utilitarian approach, which indeed dominates 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. Formally, the utilitarian social welfare can then 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 due to Gorman and Debreu, subgroup separability implies that the evaluation criterion can be represented by an additive function.)

In the presence of risk, things are less easy. 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. Either one 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 and then potentially imposes on the population a degree of risk aversion that appears paternalist. This is a classical problem in social ethics (Harsanyi 1955 viewed it as a key justification of utilitarianism), and it has been recently mentioned in the context of discounting by Kaplow and Weisbach (2011).

Fleurbaey (2010) proposed a compromise. The idea is 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 informed preferences when the evaluator has information about the final distribution. Suppose for instance that individuals are willing to take a risk but that it is known 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 they actually act against their true interests when they are willing to take the risk. When making a decision under risk, each individual focuses on his own payoffs and ignores the correlation with 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 if some of them are acting against their interests. Fleurbaey (2010) shows that when the requirement to respect risk preferences is limited to the case of perfect correlation, other criteria than utilitarianism become acceptable, permitting a greater degree of inequality aversion. There is a theorem stipulating 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 $Eu(c)$ 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 $\sum_i \varphi(u(c_i))$. Then the expected EDE criterion takes the form

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

where φ^{-1} denotes the inverse function and n is the number of individuals.

In Fleurbaey and Zuber (2012), 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 discount rate obtained for the additive social welfare function $\sum_i \varphi(u(c_i))$, 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 reflecting the attitude of the criterion to population size – this issue 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 first 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 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 (i.e., the concavity of function φ) is strong, social welfare as measured by the EDE is then close 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, showing that the difference between criteria may be far from negligible.

This compels us to mention another issue that cannot be ignored when the risk of extinction is considered. In the Stern Review there is a 0.1% 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). The underlying utilitarian reasoning is that the expected value of total utility is equal to

$$U(c_0) + \frac{999}{1000}U(c_1) + \left(\frac{999}{1000}\right)^2 U(c_2) + \cdots$$

The computation of the discount rate then involves an additional term in the formula of the marginal change in social welfare:

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

implying

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

which is approximately equivalent to adding 0.001 to the initial value (when the latter is close to 1).

There is, however, an issue that such an approach raises. 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. Total utilitarianism, implicitly adopted above, adds utilities considering that a new member with a positive utility always improves social welfare. Critical-level utilitarianism adds utilities but deducts a fixed amount for every new member. In other words, it computes the sum of $U(c_i) - \alpha$, which means that adding a new member to society is considered beneficial only if his utility is above α. The introduction of the critical level, however, does not affect the marginal utility of consumption for existing 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. The computation of the discount rate for this third approach is substantially different and, to the best of our knowledge, has not been explored.

With the EDE criterion introduced in this section, one has various options for the critical level, but unlike utilitarianism there is only one constant critical level that can be taken, and this is the lowest possible utility. Another salient option is to take a critical level that is equal to the EDE itself. 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 retained, the discount rate contains an additional term that is negatively or positively related to the correlation between the well-being of the beneficiaries of the investment and the population size (see Fleurbaey and Zuber's paper for details).

Conclusion

Let us briefly wrap up the argument of this paper. The discount rate only serves 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, as 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 paper 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. In the very long run, Weitzman's observation that the worst-case scenario drives the discount rate has to be supplemented by the fact the situation of the worst off at both ends of the investment will also drive the value of the discount rate.

Therefore, if climate policies such as mitigation efforts are paid by the affluent populations of the present generations and greatly benefit the worst off of the distant future generations in the most catastrophic scenarios, it is very likely that the correct discount rates for the evaluation of such policies should be 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 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 been made already by Stern (2007). The discount rate is useful to evaluate small transfers of consumptions across individuals living at different times. It is not the 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 attention to the selection of such criteria on sound ethical principles.

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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 2 million years, comprising 80000 generations (a generation is 25 years), and we assume that 4000 generations (100,000 years) have already lived up to now. The world population is assumed stable from now on, with 3 billion members per generation (three generations overlap at any given moment in time). The past population since the origins is assumed to have grown from an initial number of two individuals at the growth rate of 0.3% per generation until 10,000 years ago, when the growth rate rose to 2.62% per generation.

There are two dynasties, one consuming 1 unit today and the other consuming 5 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),[1] the growth rate of per capita consumption up to now would have been 0.081% on average per generation, which seems very small, but would imply that the last generation in 1.9 million years should consume about 10^{26} as much as now, a big number that is probably much greater than the number of planets in the whole universe (the number of stars is estimated below 10^{24}).

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% and consumption grows by a factor 625. Inequality remains constant between the two dynasties. After the growth transition, future generations consume 25 times our current consumption level.

In order to introduce risk we also assume that with a 20% probability, consumption will stagnate forever from now on, and that only 40,000 generations live (one million years). This is the unfavorable state.

We retain the utility function

$$U(c) = \frac{1}{1-\rho}\left(c^{1-\rho} - \hat{c}^{1-\rho}\right),$$

and take $\varphi(u) = \frac{1}{1-\varepsilon}u^{1-\varepsilon}$, with $\rho = \varepsilon = 2$ and $\hat{c} = 0.02$. (This is half the first generation's consumption.) We consider a policy that is paid only by the rich dynasty of the 4000th generation (i.e., the present generation) and benefits equally to every dynasty in future generations, i.e., we ask how much $1 equally shared between a rich and a poor in the future is worth compared to $1 paid by a rich today. The horizons in Table 5 are expressed in years, and discount rates are also per annum, as in the previous tables.

Table 5: Discount rate for the EDE criterion, total or critical-level utilitarianism, and average utilitarianism

Horizon	EDE	Total or CLU	Average U
50	-3.81%	-3.34%	-3.77%
100	-1.64%	-1.21%	-1.62%
200	-0.76%	-0.49%	-0.75%
500	-0.30%	-0.19%	-0.30%
1000	-0.15%	-0.10%	-0.15%

1. If 1 unit is worth $10,000 per annum, 0.04 units is slightly above $1 per day.

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

The discount rates tend to zero in the table for the largest horizons, because the difference in consumption between the donors (5 units) and the worst-off in the worst scenario (1 unit) becomes very small in terms of annual growth rate. Observe that -3% per annum implies a strong priority for the future: it means that it worth sacrificing $4.6 now to transfer $1 fifty years into the future.

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