

# Agreeing to disagree on climate policy

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**Disagreements about the value of the utility discount rate—the rate at which our concern for the welfare of future people declines with their distance from us in time—are at the heart of the debate about the appropriate intensity of climate policy. Seemingly small differences in the discount rate yield very different policy prescriptions, and no consensus “correct” value has been identified. We argue that the choice of discount rate is an ethical primitive: there are many different legitimate opinions as to its value, and none should receive a privileged place in economic analysis of climate policy. Rather, we advocate a social choice-based approach in which a diverse set of individual discount rates is aggregated into a “representative” rate. We show that performing this aggregation efficiently leads to a time-dependent discount rate that declines monotonically to the lowest rate in the population. We apply this discounting scheme to calculations of the social cost of carbon recently performed by the US government and show that it provides an attractive compromise between competing ethical positions, and thus provides a possible resolution to the ethical impasse in climate change economics.**

A central feature of the economic analysis of climate change policy is that it requires us to weigh costs and benefits that are distributed across very long time horizons. Most of the benefits of policies that aim to reduce greenhouse gas emissions will be realized only by future generations, whereas their costs must be borne by us today. Any sensible climate policy thus needs to trade off future benefits against current costs.

Economists who study climate change have a standard tool for aggregating consequences that are distributed across time. They make use of dynamic social welfare functions of the discounted utilitarian type. Let  $c(t)$  be a measure of the set of goods and services we consume at time  $t$ . Then under discounted utilitarianism, a policy that gives rise to a sequence of consumption  $c(t)$  is preferred over a policy that gives rise to the sequence  $\tilde{c}(t)$  if and only if

$$\int_{\tau}^{\infty} U(c(t))e^{-\delta(t-\tau)} dt > \int_{\tau}^{\infty} U(\tilde{c}(t))e^{-\delta(t-\tau)} dt, \quad [1]$$

where  $\tau$  is the current time,  $U(c)$  is a utility function assumed to be increasing and concave ( $U' > 0$ ,  $U'' \leq 0$ ), and  $\delta > 0$  is the utility discount rate, also known as the pure rate of time preference. This approach aggregates future utilities additively, but down-weights welfare consequences that are distant in time by an exponentially declining discount factor  $e^{-\delta t}$ . The larger the discount factor  $\delta$ , the more this welfare function favors policies that benefit the present rather than the future.

The normative justification for using the exponentially discounted utility model for dynamic welfare analysis was laid out forcefully in the axiomatic work of Koopmans (1). This model respects two attractive properties of dynamic choice (independence and stationarity; see e.g., ref. 2) and gives rise to optimal plans that are time-consistent—the mere passage of time does not cause us to alter the plans we made in the past. It thus has become the standard method for policy choice and evaluation in dynamic contexts, including climate change.

## Whose Discount Rate?

Although there is a near-unanimous adherence to the social welfare function defined in Eq. 1 in climate economics, there are

substantial and persistent disagreements about the appropriate value of the discount rate  $\delta$ . These disagreements are encapsulated by a long-standing debate between two of the most well-known proponents of the field—Nicholas Stern and William Nordhaus—who recommend values for  $\delta$  of 0.1% per year and 1.5% per year, respectively. Although a 1.4% difference in  $\delta$  may not seem like much, it has an enormous effect on policy recommendations. Stern (3) recommends aggressive mitigation investments, whereas Nordhaus's analysis (4) argues for a much less intensive climate policy. This is reflected in the fact that the value of the social cost of carbon (SCC; the estimated welfare cost of emitting one additional ton of  $\text{CO}_2$ ) obtained by Stern is more than 10 times Nordhaus's value. The cause of these widely different policy recommendations may be traced largely to the different discount rates the two authors assume in their analysis (4).<sup>†</sup> Other commentators have argued for their own preferred values of  $\delta$ , with no convergence to a single unanimously agreed upon value in sight. Given the important effect  $\delta$  has on policy prescriptions, this disagreement has led to an uncomfortable stalemate in climate change economics, which has led some to question the value of economic models of the issue (5).

Our view is that the choice of  $\delta$  represents a primitive ethical judgment—it captures how much one cares about the welfare of future generations. As such, it is a parameter that is unique to each person; much like the moral legitimacy of the death penalty or abortion rights, it is the kind of thing reasonable people may reasonably disagree about.<sup>‡</sup> Once we adopt this position, it

## Significance

**The social cost of carbon—the cost to society of an additional ton of  $\text{CO}_2$  emissions—is a crucial measure of the desirable intensity of climate policy. The models economists use to calculate it, however, are highly sensitive to the choice of discount rate, which measures our concern for the well-being of future generations. Different economists favor different values, and this leads to radically different policy prescriptions. We present a method for combining a diverse set of discount rates into a single “representative” rate and apply it to the analysis of the social cost of carbon performed by the US government. This approach may help resolve ethical conflicts and, hence, lead to consensus policy recommendations.**

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<sup>‡</sup>The Stern review also initially chose a low value of the elasticity of marginal utility (i.e.,  $\eta = 1$ , where  $\eta$  is defined in Eq. 5 below), thus compounding the differences between its analysis and that of Nordhaus (who uses  $\eta = 2$ ). The postscript to the review, however, contains a sensitivity analysis over  $\eta$ . Arguably,  $\eta$  has more of a positive flavor than  $\delta$ , as it measures aversion to inequality, including contemporaneous inequality, and thus may be estimated empirically, as we discuss below. There is no conceptual difficulty in accounting for heterogeneous utility functions too (see e.g., refs. 7, 8), but analytic solutions for the representative discount rate are not possible in this case. We keep to the case of common utility functions to simplify the exposition.

<sup>§</sup>Remarkably, both Stern and Nordhaus enunciate this position in their writings. Stern (6): “Value judgements are, of course, precisely that and there will be many different positions.” Nordhaus (4): “It should be clear that alternative ethical perspectives are possible... [and] provide vastly different prescriptions about desirable climate change policies.” Both authors nevertheless perform their analysis with a single preferred value of  $\delta$ .

becomes clear that the economist's role is not to impose his or her own preferences on society, but rather to adopt a welfare framework that aims to represent the distribution of ethical views. There are no objectively "correct" values of  $\delta$ , only different ethical positions, and each should be given some weight in policy prescriptions. The analysis of climate policy thus becomes an exercise in social choice—we need to aggregate the diverse preferences of individuals into a representative discount rate and use this to evaluate policy options.

### Discounting Under Disagreement

Individuals with different discount rates have different preferences regarding the timing of consumption. Those with high discount rates will have stronger preferences for immediate consumption, whereas those with low discount rates will be more willing to defer consumption into the future. Given a set of policy choices (e.g., global mitigation effort and savings rates), the total quantity of global consumption is determined by technological and climatic factors. To assign a value to this consumption path, we need a rule for allocating global consumption between individuals with different discount rates. It is natural to require that such an allocation be efficient. An allocation is efficient if it cannot be altered to make one person better off without making someone else worse off.

Efficient consumption allocations may be determined through the follow procedure. Let global consumption per capita at time  $t$  be  $C(t)$ . Suppose a planner allocates consumption  $c_i(t)$  to individual  $i$  with discount rate  $\delta_i$  according to

$$\max_{c_i(t)} \sum_i w_i \int_{\tau}^{\infty} U(c_i(t)) e^{-\delta_i t} dt \quad \text{s.t.} \quad \sum_i c_i(t) = C(t), \quad [2]$$

where  $w_i$  is a set of positive Pareto weights, with  $\sum_i w_i = 1$ . It is well known that allocations  $c_i(t)$  chosen in this manner will be efficient. To ensure equal treatment, we further assume that  $w_i$  is chosen to coincide with the proportion of individuals in the population with discount rate  $\delta_i$ .

Given this allocation rule, which discount rate should we use to evaluate global consumption streams  $C(t)$ ? To answer this question, we need to find a representative agent whose preferences over global consumption streams will be derived endogenously from the efficient sharing rule defined in Eq. 2. This approach was pioneered by ref. 7 and was generalized by us in ref. 8. Formally, we solve for the efficient allocations  $c_i^*(t)$  that solve the optimization problem in Eq. 2. These solutions will depend on the global consumption stream  $C(t)$  and on time, i.e.,  $c_i^*(t) = c_i^*(C(t), t)$ . We then can define the group's instantaneous welfare from global per capita consumption  $C(t)$  through

$$V(C(t), t) = \sum_i w_i U(c_i^*(C(t), t)) e^{-\delta_i t}. \quad [3]$$

This function captures the group's preferences over global consumption streams  $C(t)$ . The utility discount rate of the representative agent is then given by minus the elasticity of marginal welfare with respect to time:

$$\delta^*(C(t), t) = -\frac{\partial^2 V / \partial C \partial t}{\partial V / \partial C}. \quad [4]$$

To simplify the analysis,<sup>8</sup> assume that agents' utility functions  $U(c)$  take the widely used isoelastic form

$$U(c) = \begin{cases} \frac{c^{1-\eta}}{1-\eta} & \eta \neq 1 \\ \ln c & \eta = 1 \end{cases}. \quad [5]$$

Here  $\eta \geq 0$  is the elasticity of marginal utility, which measures aversion to consumption inequality. To understand its interpretation, imagine that a rich person with consumption  $c$  donates \$1 to a contemporaneous poor person who has consumption  $c/2$ , but that only a fraction  $x$  of this transfer arrives in the poor person's pocket. With utility function 5, this transfer is socially desirable if  $x > (1/2)^\eta$ . Thus, for  $\eta = 1$ , half of this "leaky" transfer needs to reach the poor person for it to be socially beneficial, but for  $\eta = 2$ , only a quarter of the transfer needs to arrive. In general, the larger  $\eta$  is, the more averse we are to consumption inequality and the more we are willing to pay to decrease inequality. We will discuss estimated values for  $\eta$  below.

With the isoelastic utility function 5, the group's discount rate in Eq. 4 reduces to (see derivation in Appendix)

$$\delta_\eta^*(t) = \frac{\sum_i \delta_i (w_i e^{-\delta_i t})^{\frac{1}{\eta}}}{\sum_i (w_i e^{-\delta_i t})^{\frac{1}{\eta}}}. \quad [6]$$

For this utility function, the group's discount rate does not depend on  $C(t)$ . It is simply a weighted sum of the individuals' discount rates, with time-dependent weights  $y_i(t) := (w_i e^{-\delta_i t})^{\frac{1}{\eta}}$ .

Defining the expectation operator  $E x_i := \sum_i x_i y_i(t) / \sum_i y_i(t)$  and differentiating Eq. 6 with respect to time, we find

$$\frac{d}{dt} \delta_\eta^*(t) = -\frac{1}{\eta} (E \delta_i^2 - (E \delta_i)^2) < 0. \quad [7]$$

Also, letting  $i = L$  index the agent with the lowest discount rate, we have

$$\lim_{t \rightarrow \infty} \delta_\eta^*(t) = \lim_{t \rightarrow \infty} \frac{\delta_L + \sum_{i \neq L} \delta_i (w_i / w_L)^{\frac{1}{\eta}} e^{-(\delta_i - \delta_L)t/\eta}}{1 + \sum_{i \neq L} (w_i / w_L)^{\frac{1}{\eta}} e^{-(\delta_i - \delta_L)t/\eta}} = \delta_L. \quad [8]$$

Thus, although each member of the group has a constant discount rate  $\delta_i$ , the efficient discount rate for the group as a whole is time dependent and declines monotonically to the lowest rate in the population.

### Disagreement and the Social Cost of Carbon

In this section, we demonstrate how the theory of discounting under disagreement may be applied to the analysis of climate policy. We focus on the effects of discounting on estimates of the SCC, perhaps the most important summary statistic in climate change economics. As mentioned above, the SCC measures the welfare cost of an additional unit of CO<sub>2</sub> emissions to current and future generations. In a "first-best" world, it coincides with the optimal tax rate on CO<sub>2</sub> emissions. The SCC has been the subject of several studies commissioned by national governments, including a recent one by an Interagency Working Group (IWG) in the United States (9, 10), which we will use as a point of comparison in our analysis.

To estimate the SCC, we need an integrated model of the climate-economy system that captures how the trajectory of future global temperatures change in response to an additional unit of CO<sub>2</sub> emissions, how these climatic changes affect the global economy over time, and finally, how these impacts alter global consumption and welfare. We will make use of a version of the well-known Dynamic Integrated Climate Economy (DICE) model (4). To make our analysis directly comparable with the IWG's, our version of DICE makes use of the same socioeconomic

<sup>8</sup>See refs. 7 and 8 for a general analysis with arbitrary, possibly heterogeneous, utility functions.



discount rate. Although public reasoning and debate may help us refine our positions, the outcome of this process is unlikely to result in a unique consensus. As Amartya Sen (20) noted, “Even the most vigorous critical examination can still leave conflicting arguments that are not eliminated by impartial scrutiny.” How can rational policy recommendations be made in an environment characterized by such persistent and quantitatively important disagreements?

We have argued for a social choice-based approach to climate policy that reflects the diversity of opinion on ethical matters. This has both pragmatic and philosophical advantages. Pragmatically, our approach provides a formal mechanism for avoiding impasses caused by ethical disagreements. Everyone’s opinion counts, and no one can claim that policy recommendations are derived from morally high-handed modeling assumptions. Philosophically, our method draws on a long democratic tradition in social choice theory that assigns each preference an equal weight in public decision making to arrive at a consensus acceptable to all.

We hope the techniques we have identified will help resolve debates about “the” appropriate value of the discount rate and allow research attention to focus instead on empirical questions such as the specification of the damage function in integrated assessment models, as well as comprehensive quantifications of the uncertainty in the technological and climatic components of these models (21). Although ethical assumptions are important drivers of the policy recommendations from integrated assessment models, this should not be seen as a strike against them. Ethical positions will always be irreducibly diverse, but we may nevertheless respectfully agree to disagree.

## Appendix

We can solve the maximization problem in Eq. 2 by the method of Lagrange multipliers. The Lagrangian is

$$\max_{c_i(t)} \sum_i w_i \int_{\tau}^{\infty} U(c_i(t)) e^{-\delta_i t} dt - \lambda(t) \left( \sum_i c_i(t) - C(t) \right), \quad [10]$$

where  $\lambda(t)$  is a sequence of Lagrange multipliers. The first-order conditions for the efficient allocations  $c_i^*(t)$  yield

$$c_i^*(t) = U'^{-1} \left( \frac{\lambda(t) e^{\delta_i t}}{w_i} \right), \quad [11]$$

and the constraint  $\sum_i c_i(t) = C(t)$  implies that

$$\sum_i U'^{-1} \left( \frac{\lambda(t) e^{\delta_i t}}{w_i} \right) = C(t). \quad [12]$$

Now assume that  $U(c)$  is an isoelastic utility function, as in Eq. 5. Then,  $U'^{-1}(x) = x^{-\frac{1}{1-\eta}}$ . Substituting this relationship into Eq. 12 allows us to solve for  $\lambda(t)$  in terms of  $C(t)$ . This expression for  $\lambda(t)$  in turn may be substituted into Eq. 11 to find

$$c_i^*(t) = \frac{(w_i e^{-\delta_i t})^{1/\eta}}{\sum_i (w_i e^{-\delta_i t})^{1/\eta}} C(t). \quad [13]$$

Substituting this expression into Eq. 3, we find that the group’s instantaneous welfare at the optimal allocation may be written as

$$V(C(t), t) = \frac{C(t)^{1-\eta}}{1-\eta} \beta(t), \quad [14]$$

where the group’s effective discount factor  $\beta(t)$  is given by

$$\beta(t) = \left( \sum_i (w_i e^{-\delta_i t})^{1/\eta} \right)^{\eta}. \quad [15]$$

The group’s discount rate  $\delta_{\eta}^*(t)$  then is determined by Eq. 4, which reduces to

$$\delta_{\eta}^*(t) = -\frac{1}{\beta} \frac{d\beta}{dt}. \quad [16]$$

Straightforward algebra then yields the expression for  $\delta_{\eta}^*(t)$  in Eq. 6.

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